# EFFECT OF NON ENZYMATIC BROWNING OF CHICK FEED ON THE GROWTH RATE OF CHICKS

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1979

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1985

EFFECT OF NON-ENZYMATIC BROWNING OF CHICK FEED ON THE GROWTH RATE OF CHICKS

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ACKNOWLEDGEMENTS

The author wishes to express her sincere appreciation to Dr. Sue Knight, for her guidance, support, expertise, and help rendered in completing this thesis. Appreciation is also expressed to Dr. Lea Ebro and Dr. William Warde for their willingness to serve as advisory committee members and for their help and advice. The help given by the Animal Science Department of Oklahoma State University -- materials, facilities, aid, and advice is gratefully acknowledged. Special thanks is expressed to Dr. Robert Teeter, for giving his expertise generously during this entire study. The author wishes to express her thanks to Mr. Gene Murray of Poultry section and Mr. Earl Knight for their help during the course of the study.

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# CHAPTER I

## INTRODUCTION

Birch, Spencer and Cameron (1) have quoted Brillat Savarian who once said, "Tell me what you eat and I will tell you who you are." Many of us may not agree with this provacative remark, yet this statement helps to remind us that our body is built from the food we eat. Although a lot of people claim that they "live to eat," everyone must acknowledge the fact that they have to "eat to live;" it is hard to escape from this fundamental importance of food.

There are known international differences in foods. However, all these foods can be split up into the same basic components and the differences between them exist only in species, shape, and flavour, and not in the real nutritional effect. The primitive tribesman uses this word "food" for a few familiar substances such as flesh, fruit, or roots which satisfy his pangs of hunger when he eats them.

Scientifically, "food" is defined as that which is necessary for the health, growth, and normal functions of living organisms (1). Basically, food is a mixture of chemicals, and we can separate the food of our choosing into chemically identifiable parts. We are able to recognize the chemical class to which each of the separate parts belong, and thus be able to predict their behaviour on cooking, or their behaviour in the body after eating.

Most of the operations used in culinary preparation of food such

as boiling, baking, broiling, roasting, and frying, and also of large scale processing such as blanching, pasteurization, and sterilization entail the application of heat. The conditions of processing by heat are constantly improved to permit the optimal retention of nutrients and organoleptic quality. The application of heat is carefully controlled to avoid the formation of harmful substances, but still there are nutrient losses associated with heating of food. The Maillard reaction (non enzymatic browning) plays an important role in food technology, and therefore, the biological consequences of this reaction have to be studied further.

## Significance of the Problem

Before man discovered fire, he lived on raw foods, wild fruits, and nuts together with eggs and raw meat from the animals he killed, supplemented with fish and shell fish if he lived near water. Nowadays, most of the foods consumed by man are treated in some way or the other to improve texture, colour, or appearance.

Maillard (2), in 1912, observed that solutions of amino acids heated in the presence of reducing sugars, developed a yellow brown colour. He hypothesised that this reaction occured in vivo and was of importance in diabetes. However, the biological importance of the Maillard reaction was not recognized by medical scientists for a long time. As a result of the Maillard reaction, nutrients were bound; but the loss of nutrients due to the binding was thought by human nutritionists to be negligible. Patton (3) studied the effect of

the Maillard reaction on nutritive value of protein and found significant losses of lysine, arginine, tryptophan, and histidine.

Kawamura (4) reported that a decrease in the level of non reducing sugars, available lysine, and whiteness paralleled the heating time of defatted soybean flakes at 100° C to 200° C. The non reducing sugars were presumed to undergo hydrolysis upon heating and the reducing sugars formed (fructose, glucose, and galactose) were responsible for the Maillard reaction.

A recent study done by Knight and Hanson (5), at Oklahoma State University showed that browing of bread ingredients materially decreased their nutritive value. Browned mixtures of flour, oil, yeast, sugar (glucose), dried eggs, vitamins, and minerals were fed to chicks. They found that the chick growth was retarded when the chicks ate a browned feed as compared to the same feed unbrowned. Kimiager, Lee and Chichester (6), reported that nutrient binding during browning was accelerated if the sugar present was a reducing sugar. In the study done by Knight and Hanson (5), the diet given to the chicks had adequate nutrients and calories to support maximal growth. The chicks that received the browned feed, whether lightly browned or darkly browned, gained little, if any, weight. But the chicks on the unbrowned feed gained an average of 16 gms per day. When the browned feed was supplemented with lysine and casein, the chicks gained weight rapidly. From these results it appeared that binding due to browning was far from negligible; although in a subsequent trial when another source of glucose was used, a commercially available hydrolysed corn sweetner, the effect was less apparent.

The food manufacturers are increasingly using corn sweetners made from hydrolysed or isomerised corn starch in place of the more expensive sucrose. These sweetners are basically a high percentage of glucose and/or fructose, both reducing sugars, but perhaps not all sources are as uniformly hydrolyzed or isomerised thus changing the speed of participation in the browning (5).

Lysine one of the essential amino acids for man and chicks is readily bound in the Maillard reaction. A deficiency of lysine can be easily detected in a growing chick (7). The use of enzymatically produced corn sweetners rather than sucrose by the food industry is increasing. Since, nutrient binding during browning is increased in the presence of such sugars, it should be determined, based on chick growth, whether changing the sugar in food products increases nutrient loss due to the Maillard reaction.

## Purpose of Objectives

The purpose of this study is to assess whether different sources of sugar affect the growth-supporting quality of the chick feed. Specifically, the study explores the following objectives:

1. To assess if different sugars in a browned feed affect the growth supporting quality of the feed.

2. To assess if the amount of lysine that is available in the browned feed affect the growth supporting quality of the feed.

3. To determine whether the sugar used or browning of the feed affect the amount of feed consumed by the chicks.

## Hypotheses

The following hypotheses were formulated for this chick essay.

Hypothesis 1. There will be no significant difference in the growth rate of chicks caused by the use of different sugars in a browned or unbrowned chick feed.

Hypothesis 2. There will be no significant differences in the lysine content of the feed between browned and unbrowned rations or due to types of sugar and browning.

Hypothesis 3. There will be no significant differences in the amount of feed consumed by the chicks due to different sugars in a browned or unbrowned feed.

## Assumptions

The following assumptions are made for this study:

1. The growth rate of chicks will reflect the nutritional quality of the feed.

2. Homogeneity of treatments is assumed.

3. Lysine is an essential amino acid for both man and chicks.

Therefore, based on the growth of chicks, a similar pattern for man is assumed.

## Definitions

Definitions for the experimental study are as follows:

Essential amino acids are amino acids that cannot be synthesised in the body and must be obtained from foods (8).

Limiting amino acids are the amino acids that are in short supply

in the incomplete protein. If the only source of protein in the diet is an incomplete protein, the one or more essential amino acids inadequately supplied would be the first ones to be used up from the amino acid pool. After which, the inadequately supplied essential amino acids would limit protein synthesis in the body (9).

Maillard reaction is a non enzymatic browning reaction wherein amino groups in proteins when heated react with reducing sugars to form a brown, insoluble, and enzyme resistant substance (10).

Reducing sugar is a sugar which has an aldehyde or ketone group. All monosaccharides and some polysaccharides that have the ability to reduce an alkaline solution of cupric ions without undergoing hydrolysis are said to be reducing sugars (11).

# CHAPTER II

# REVIEW OF LITERATURE

The browning of food associated with heating rather than enzyme action is called the Maillard reaction. A review of the history and research of this reaction is most interesting as are the effects of this reaction in different food products. Also a comparison of the Maillard reaction with other types of food browning is reviewed.

## History

Louise-Camille Maillard, a French Scientist, first observed the reaction now named for him in about 1912 (2). In 1972 (12), Kawamura published a brief historical review of this reaction on the sixtieth anniversary of its first being reported by Maillard. There was controversy in both who first discovered this browning reaction as well as who first named it.

In the year 1911, Maillard reported a study on the condensation of amino acids by using glycerol (13). A few months later, Maillard used sugars instead of glycerol to react with amino acids forming polypeptides. It was found that the aldehyde groups in sugar had a greater effect on the amino acids than did the hydroxyl groups in glycerol. This led to the discovery of the Maillard reaction.

Arthur Robert Ling, in 1908 mentioned the effect of kilning or heat drying as:

> At the second stage of kilning when the range of temperature is from 120° C to 150° C the mellowing "auto-digestion" is continued . . . flavouring and colouring matters are produced . . . when these amino-compounds produced from proteins are heated at 120° C to 140° C with sugars such as ordinary glucose or maltose, which are produced at this stage of process, combination occurs. The precise nature of the compound produced is unknown to me, but they are probably flucosamine like bodies. (p. 494)

Ling also described the reaction of heating glucose with asparagine which produced darkening in colour. Maillard is one of his papers had cited Ling's report on heat drying (14).

During World War I (1914 to 1918), Swiss scientists could continue research, but the French scientists could not do so easily. Therefore, much of the early work on the Maillard reaction was done by Swiss scientists rather than by Maillard. In 1916 a Swiss, Ame Pictet, reported the formation of pyridine and isoquinoline bases from acid hydrolyzate of caesin in the presence of formaldehyde (15). However, Maillard claimed priority over Pictet in the discovery of the condensation of amino acids with aldehydes or sugars, and his claim is generally upheld (14).

The naming of this reaction had also been a point of interest. In 1963 and 1973, Ellis was cited by Reynolds and Strahiman (16) as the first person to call this browning the Maillard reaction. However, examination of the subject indexes of Chemical Abstracts by Kawamura (14) showed that the Chemical Abstracts used the index term "Maillard Reaction" up to Volume 43 (1949) of the Chemical Abstracts. Thompson and Patron named this reaction in 1950 (17), but Barnes and Kaufman (18) used the term in one of their papers published in 1947.

However, Maillard himself wrote often "my reaction" (ma reaction). Therefore, it was a simple conclusion that the first namer of this

browning reaction was the original author Maillard himself. Litner in 1912 (19), and Ruckeschel in 1914 (20), used the phrase "by the process of Maillard." It was of interest to find these two German scientists, concerning themselves with a reaction recently discovered by a French scientist, especially since World War I was in progress.

## Nutritional Aspects of the Maillard Reaction

The Maillard reaction is very important in food technology since it takes place during heat treatments and during food storage at room temperature (21). This reaction seems to create both positive and negative characteristics in food colours and flavours. However, the nutritional quality of food (with respect to protein and total calories) undergoing Maillard reaction is always reduced.

The Maillard reaction includes all the reactions involving a ketone or aldehyde and amino group. The ketone or aldehyde groups are usually from sugars, and the amino groups are from amino acids. Some researchers have claimed that the Maillard reaction also includes reactions occuring under the same conditions when the aldehyde or ketone is produced by the oxidation of a fatty acid, but these reactions are not well developed (21, 22).

The biological consequences as perceived by Maillard seem to fall into three categories and are of interest in both biochemistry and physiology. The three categories are as follows (23):

1. Destruction of sugar and amino acid resulting in decreased protein quality and quantity.

2. Formation of detrimental substances of an anti-nutritional or toxic nature.

3. Formation of favourable psychosensorial and flavour aspects wherein some molecules appearing during the Maillard reaction cause appetizing colours and aromas.

During the Maillard reaction several rather complicated chemical reactions take place (24). These have been simplified in the following schematic representation.

Sugar + Amino Acid

Intermediate Products Called Premelanoidins

Fission — Strong Degradation — Mild

Maillard Products

(Brown Melanoidin Polymers)

The Maillard reaction has been found to occur over a wide range of temperatures, ranging from high temperatures obtained during processing down to ambient storage temperatures. Of the nutritional changes that take place during Maillard reaction the most noteworthy is probably the decrease in the bioavailability of lysine as well as several other essential amino acids. The Maillard reaction involves sugar losses as well as amino acid binding and losses (25).

## Fate of Maillard Products

Nutritional damage to foods and feeds caused by a variety of processes has usually been considered as a consequence of alterations in protein digestibility or of changes in availability of amino acids, particularly lysine. Alterations in animal performance were largely attributed to alterations in amino acid availability. In studies with

rats, when caesin, egg, soy, or fish proteins were heated (autoclaved) in the presence or absence of carbohydrate, extending the heating time resulted in reduction in the rats' growth rate and food intake; and the net protein ratio of the feed was also reduced (26).

The extent to which these reductions took place, varied with the protein studied, the carbohydrate present, and the duration of autoclaving. A study done by Knipfel (27), on weanling rats showed increased nutritional damage, when they were fed caesin, egg, or soy protein heated in the presence of carbohydrate. However, metabolic transit studies performed on rats fed Maillard products indicated that Maillard products were partially absorbed from the intestine (28).

The brown melanoidin pigments were the final products in the Maillard reaction and were amphoteric polymers (29). But all the brown pigments were not the same. Fahey, Williams and Mcharen (30) revealed that a diet containing brown pigments separated from cane molasses (composed primarily of sucrose, a non reducing sugar) stimulated the growth of rats. In contrast, diets containing Maillard reaction products formed from a reaction mixture of reducing sugars, whole proteins, or amino acids, caused diarrhea as well as depressed growth rates (31). These varied responses to browned products were ascribed to chemical differences among the browned products.

Although some had commented on possible toxic effects of Maillard products (23, 25), Homma and Fujimuki (32), studied the growth responses of rats that were fed a diet with or without melanoidins. They reported no unusual growth behaviour or significant differences in weight gains in the rats fed melanoidin-containing diets throughout a two-month period as compared to the control

animals. After the feeding experiments, the digestive organs of the rats were pathologically examined, and no differences were observed between the controls and the melanoidin groups. Others, however, have reported less innocuous effects.

Nair, Oste, Asp and Pernemalm (33) studied the absorption and distribution of radioactive Maillard compounds formed by the reaction of a glucose and lysine mixture. The solutions were given to rats by gastric intubation and the rats were kept in metabolic cages. The rats were sacrificed at different intervals of time; and the radioactivity in the various parts of the gastrointestinal tract, urine, and feces were measured. There were some radioactive compounds retained in the rats livers; of these liver compounds one compound contained three other substances besides glucose. These researchers believed this compound to be a metabolite of some Maillard product deposited in the stomach, which was absorbed and metabolized in the body. Nair et al. also found that severe heat treatment produced a number of polymeric products which inhibited digestion, hindered absorption, and created toxic and carcingoenic effects. Also Erbersdobler, Von Wangenheim, and Hanichen (34) reported that Maillard products limited digestion and absorption of heat treated radioactive protein. A study by Horikoshi, Ohmura, Gomyo, Kuwabara, and Ueda (35) on the effects of browning reactions on the intestinal microflora of the rat showed that oral administration of Maillard products in vivo caused an increase in the growth of aerobic and anaerobic lactobacilli in the microflora of the rat. With respect to other microorganisms (enterocci, staphylococci, coliforms, and

clostridia), no significant differences were observed between the test group and the control group. The changes in the microflora were discussed in relation to the alteration of physiological states in the digestive tracts and the direct action to the tested substances on the lactic group. However, a recent invitro study done at Oklahoma State University on the growth inhibition of microorganisms in raw milk and autoclaved milk, showed growth inhibition of microorganisms, specifically P.Fragi which was the test organism. Other organism tested that showed growth inhibition were P.Fluorescens, S.lactis, S.aureus, E.coli, B.subtillus, and K.fragilis (36).

Lee, Kimiager, Pintauro and Chichester (37) conducted a long term study on rats to see the physiological effects of feeding a browned product (egg albumin with glucose). Significant effects directly related to the browned product were noticed. The rats that were on the browned diet showed increased blood urea nitrogen, serum glucose, serum glutamate-oxalate transaminase, serum alkaline phosphatase, and urine specific gravity. A decrease in hemoglobin and hematocrit levels were observed. Fifty per cent of the rats which were on this Maillard-browned egg albumin for three months developed vacuolated hepatocytes and after six months accumulated a black brown pigment in the liver. The pigment was granular and associated with enlargement and fatty metamorphosis of the liver cells. The researchers concluded that the browned protein had certain physiological effects that were normally note detectable from chemical or short-term nutritional evaluations commonly employed in the assessment of processed foods.

Some studies showed that heat sterilization of parenteral nutrition solutions resulted in the formation of Maillard products (38). The solutions were usually glucose-protein hydrolysate, or glucose-amino acid mixtures to which vitamins, electrolytes, and trace metal ions were added. These solutions, if hospital prepared, were assembled just prior to administration by mixing separately sterilized glucose and amino acid solutions under a laminar flow hood. However, some of the commercially available parenteral solutions containing glucose and amino acids were prepared by heat sterilization. The most widely followed practice was for hospitals to use the commercially available product.

A study was done by Stegink, Sheperd, Fry, and Filer (39) to see the effects of parenteral solutions and enteral solutions in normal adult humans. The blood and urine and plasma of these subjects were measured for the presence of Maillard products. Subjects who were fed parenterally showed the presence of a large number of compounds in the urine, and blood, which showed similarities with Maillard reaction products. The urinary excretion of zinc, copper, and iron, increased two to five times above normal during intravenous infusion of solutions containing Maillard products. The urine of the intravenously fed patients were concentrated with Maillard reaction products. However, since the Maillard reaction products when administered orally, were not found in plasma or urine, it was suggested that they:

1. Were not absorbed
2. Were absorbed and excreted at levels below the limits of detection

3. Were hydrolysed in the intestinal mucosa during absorption.

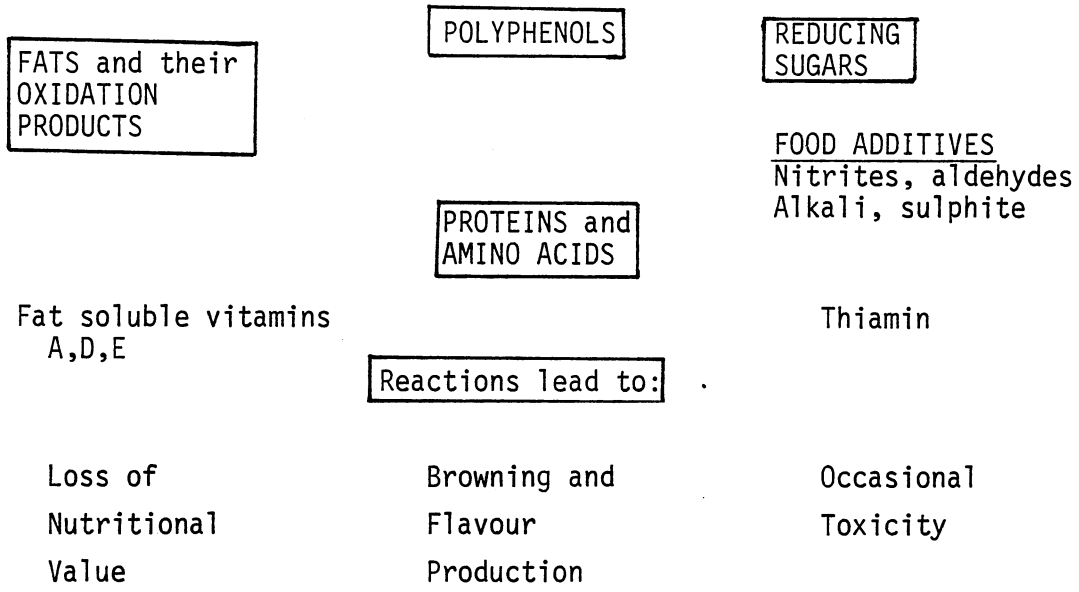
Maillard reaction products were associated with allergenic responses (40), increased carcinogenicity in the rat (41), and increased fetal death and reabsorption in the rat (42). Therefore, Stegink and co workers, felt that heat sterilized glucose-amino acid solutions presented an increased risk to the patient if Maillard reaction products were present in these solutions.

Destruction of Amino Acids

Proteins and amino acids were reported to react with fats and their oxidation products, polyphenois, vitamin B6, various chemical additives, and most of all reducing sugars (43). Figure 1 shows the results of these reactions.

Maillard reaction in food products seemed to affect the liver, by causing some type of necrosis. Research done on animals with roller dried milk powder showed hepatic necrosis which was in proportion to the heat treatment the milk powder received. The percentage of animals that died due to necrosis of the liver was less than one percent when fed with liquid milk, 40% when fed with spray-dried milk powder, and 76% when fed with roller dried milk powder (44).

A study done by Ferrando (45), parallel to the one above, used meats subjected to varying intensities of heat drying. The more heat dried meats had lowered nutritional efficiencies compared to the less dried meats, and the rats fed those meats had a greater incidence of liver hypertrophy. The hypertrophied livers showed the following types of lesions. There were early necrotic lesions with hemmorohagic




(Source: Hurell, R. F. and Carpenter, K. J.: The estimation of available lysine in foodstuffs after Maillard reaction. Prog Fd Nutr Sci. 5:159, 1981)

Figure 1. Destruction of Amino Acids

symptoms which corresponded to mild toxin damage. Also, there were cirrhotic-like lesions. Based upon nitrogen metabolism disturbances and cirrhotic lesions in the livers, Ferrando stated that Maillard reaction products developed a state that was compared to undernutrition.

It was reported in a study (46) that prolonged heating of milk resulted in products that were less allergenic. Allergy to milk protein was attributed to various molecules, including beta-lactoglobulin (a protein molecule found in milk). When this protein reacted with the lactose in milk during heating, a residue was found which had

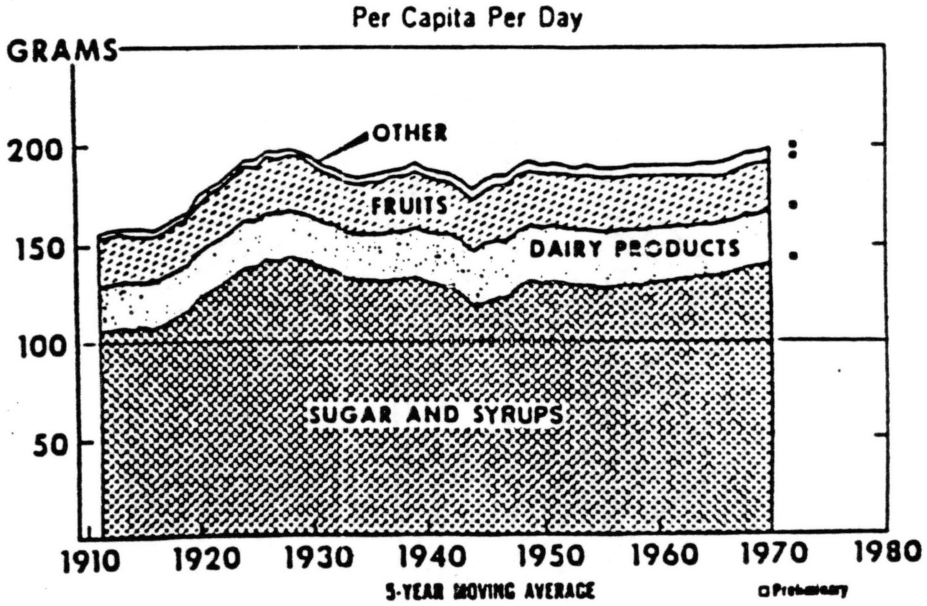
all the characteristics of Maillard reaction products. Research had shown that beta-lactoglobulins were often associated with allergic responses. However, when evaporated milk was used instead of the milder heat treated pasteurized milk, this allergy was overcome

## Maillard Reaction in Carbohydrates

To most persons "sugar" was equated with the common household foodstuff, crystalline sucrose. Historically, this naturally occuring sweetener was one of the major substances sought by man to satisfy his quest for sweet taste. The sugars which occured in foods were either natural constituents of the food generated during processing or intentionally added. At any rate, many different sugars were present in foods.

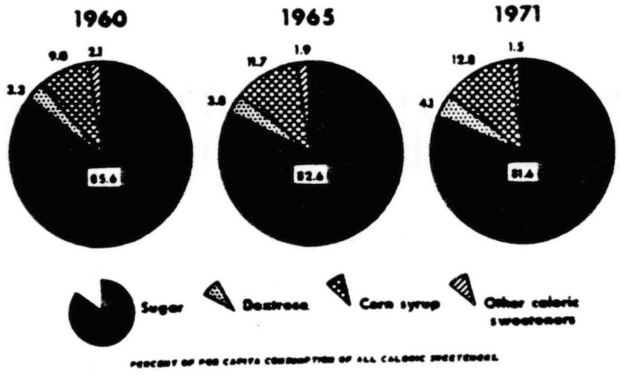
Gradually alterations in Western man's diet resulted in many unrecognized changes. The production of sugar increased rapidly after the beginning of the 20th century when it was 14 billion kg. In the 1970's it was 73 billion kg. The consumption of sugar in the European countries varied considerably. Food sources in the U.S. diet were categorized into broad groups as shown in Figures 2 and 3 (47). Table I shows an estimated percent of total sugars provided by U.S. diet accounted for as individual sugars for selected periods of time.

Sugar consumption in the U.S. was divided between manufactured products such as confections, beverages, baked goods, canned goods et cetera., and sugars used in restaurants, homes, and institutions. Much of the sugar that was formerly consumed in U.S. households is now consumed as convenience foods such as manufactured cakes, cookies, and soft drinks (48).




(From: Sipple and McNutt: Sugars in Nutrition, Academic Press, NY 1974, p. 97.)

Figure 2. Sources of Sugars in the National Food Supply, 1909-13 to 1972.




(From: Sipple and McNutt: Sugars in Nutrition, Academic Press, NY 1974, p. 98.)

Figure 3. Share of Total Caloric Sweeteners Consumed Provided by Refined Sugar, Dextrose, Corn Syrup, and Other Sweeteners, Selected Years

TABLE I

ESTIMATE OF PERCENT OF TOTAL SUGARS PROVIDED BY U.S. DIET ACCOUNTED FOR AS INDIVIDUAL SUGARS, SELECTED PERIODS

| Year | Total Sugars (gms) | Individual Sugars | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fructose (%) | Glucose (%) | Lactose (%) | Maltose (%) | Sucrose (%) | Other (%) |
| 1972 | 201 | 1.7 | 6.4 | 12.5 | 2.7 | 61.8 | 3.2 |
| 1947-49 | 192 | 2.6 | 5.6 | 14.5 | 1.7 | 62.0 | 2.4 |
| 1925-29 | 197 | 2.9 | 6.1 | 11.6 | 1.3 | 66.2 | 2.0 |
| 1909-13 | 156 | 4.0 | 3.5 | 13.6 | 1.1 | 64.8 | 2.1 |

(Source: Sipple and McNutt: Sugars in Nutrition, Academic Press, NY 1974, p. 98.)

As for the loss of sugars during the reaction, Rohan and Stewart (49) observed that sugar losses occurred more rapidly than those involving amino acids. In cocoa-bean roasting, they found that 90% of the free carbonyl containing sugars were lost, while more than half the free amino acids ramained intact. Linko and Johnson (50), noted that the type of sugar unmistakably conditioned the degradation products appearing after the Maillard reaction. Sugars with an alcohol group did not undergo browning or the Maillard reaction. For the Maillard reaction to take place, a carbonyla group (c=O) was necessary. They also noticed that the type of reducing sugar conditioned the intensity of the Maillard reaction. The shorter the carbon chain of a sugar, the greater was its reactivity.

Adrian (46) showed that sugar reactibility was also affected by

the type of protein involved in that the same sugar caused different lysine losses according to whether the protein was lactalbumin or soybean globulin as shown in Table II

TABLE II

NUTRITIONAL AND PHYSIOLOGICAL CONSEQUENCES OF THE MAILLARD REACTION

Mean reactivity of sugars during the Maillard reaction

| Sugar | Fall of Lysine (%) in | |
|---|---|---|
| | Lactalbumin | Soybean Globulin |
| Trisaccharides | 38 | 6 |
| Dissacharides | 39 | 18 |
| Hexoses | 64 | 59 |
| Pentoses | 83 | 88 |

(Source: Adrian, J.: Nutritional and psychological consequences of the Maillard reaction. World Rev Nutr Dietet. 19:71, 1974.)

## Maillard Reaction in Different Food Products

### Dairy Products

More recent research showed that, due to a high percentage of lactose and the fragility of protein during the Maillard reaction, dairy products are very sensitive to heat treatment. Milk powder

was stored for two months at 37° C then roasted for 25 minutes at 150° C, and it was found that lysine was selectively destroyed during both storage and heating (51). Repeat trials using powder showed similar results.

A comprehensive study reported in 1964 (46) delineated the damage to milk lysine during moderate heat treatments involved with pasteurization and spray drying. The concensus were that whey protein denaturation occured without causing nutritional damage and that mild heat treatment of milk and milk products were nutritionally inoffensive.

Animal Products

The different heat processing methods during industrial preparation of fish and fishmeal were responsible for a great variety in protein quality (52). Research by Miller and Milner (53), showed that cystine was the most labile amino acid. Studies done in vivo by Smith and Scott (54) confirmed the sensitivity of the sulphur containing amino acid. However, they meet in general to be stable to heat treatment.

Lea, Par, and Carpenter, (55) in 1958, reported that fishmeal and meat were much more stable as compared to milk protein when it underwent heating. Amino acid and protein efficiency losses occured only when these products were subjected to prolonged heating or treatment in complex media. Heating affected the sulphur containing amino acids present in these products.

The stability of meat proteins to heat were attributed to meat's low carbohydrate and natural acidity according to Schroedel,

Iacobellis, and Smith (56). Even after roasting at 200° C they reported that lysine seemed to be available in meat. However, when they added a small percentage of flucose, the meat became very sensitive to heat treatment. Like fishmeal, the sulphur containing amino acids were most affected by heat in meat.

Cereal Products

The behaviour of cereal products during the Maillard reaction was shown to be in between that of milk and fish. Researchers (57), determined that lysine, a limiting amino acid in cereal products was blocked and destroyed when cereal products were subjected to heat treatment. A study done by Jacquot, and Adrian in 1962 (58), to see the changes in protein efficiency of bread showed that proteins in toasted bread and breads baked without pans (French type) were very sensitive to the Maillard reaction (58). The overall nutritional quality of crumb was shown to be increased by the addition of yeast which increased the total lysine and the lysine that remained after cooking. McDermott, Pace, and Hepburn (59) also found that the proteins in bread crust and toast were damaged to a considerable extent by the Maillard reaction, and an important percentage of the lysine was lost. They also showed that bread prepared in pans browned less, and the Maillard reaction was reduced.

Researchers using an amino acid analyzer showed that bread baked using normal procedures lost 10% of its lysine. The destruction of lysine in the crust was seven times greater than in the whole bread (59). They showed that damage to lysine was caused mainly by heat.

Vegetable Products

Proteins in most leguminous seeds were shown to be resistant to moderate heat treatments as used in food preparation (60). However, when heated for a longer period of time, the sulphur containing amino acids which were already limiting amino acids in leguminous seeds were the most affected. Similarly studies done on home preparation of leguminous seeds by Tannous and Ullah (61), showed that, the seeds were remarkably stable during normal heating, but that autoclaving cuased a 10% loss of lysine and the sulphur containing amino acids. Balasundaran, Cama, Malik, and Venkatesan (62), showed that peanut protein was resistant to industrial treatment incurred in roasting and oil extractions.

## Positive Aspects of Maillard Reaction

The Maillard reaction gave rise to browning which was appreciated by the consumer, as in the case of bread crust, cookies, roasted nuts, and other vegetable products. Hodge (63) has said that the substances produced by the Maillard reaction gave rise to "technological aromas." Keeney and Day (64) showed that the Maillard reaction participated in ordor formation in cheese. Patton (65) stated that the Maillard reaction helped to create certain important flavours in dairy products.

Collyer (66) studied the flavour of bread subjected to many experiments such as hydration, presence of yeast, kneading, fermentation, baking, and staling. He observed that during fermentation, starch and protein were partially hydrolysed into simple sugars and

amino acids which reacted together during heating. The brown colour was obtained by the Maillard reaction that took place in the outer part.

Wolform, Plunkett, and Cavalier (68) noted that Maillard products formed in the roasting of coffee were a source of flavour and aroma. Newall, Mason, and Matlock (67) showed that during roasting of peanuts, desirable flavour and aroma were produced. Agabayants and Platnow (69) have attributed aroma formation during maderization of wine to Maillard products. Also, Rohan and Stewart said that the Maillard reaction was involved to a great extent in the flavour and attraction of chocolate.

## Other Types of Browning Reaction

### Lipid Oxidation Browning

One of the main requirements for browning was the presence of reducing groups such as carbonyls in aldehydes and ketones. Research showed that carbonyls are produced during the auto-oxidation of unsaturated fatty acids. One of the main products of oxidation was an aldehyde which reacted with amino acids to form the carbonyl-amino compounds which were the precursors of many browning reactions. The reaction was of some nutritional importance in that these products of fatty acid oxidation then reacted with limiting amino acids such as lysine. Research showed that during the drying of herring meal, lysine became unavailable as a result of autooxidation of fatty acids in the fish (70).

## Caramelization

A review of the caramelization process indicated that brown pigments were developed when sugars were heated. The chemical composition was very complex and varied with different heating conditions. The caramelization took place in both acid and alkaline media and the reaction products were sold commercially as viscous black syrups which gave brown or red-brown solutions when suitably diluted. Commercial caramel syrups were used to colour soft drinks, beer, wine, bakery, and grocery products. Whisky was white water when distilled and thereafter matured for several years in charred oak barrels to develop colour. Commercial whiskies were obtained by blending different distillates to achieve the characteristic flavour desired, then the colours were standardized by adding small quantities of small caramel solutions before bottling.

Caramelized sugars were regarded as harmless food additives in most countries and were used quite widely as colouring agents. In addition to producing useful colours, if accurately controlled, the browning of sugar fave rise to pleasant flavours. This fact was most often exploited in the confectionary industry. Fagerson (71) listed 96 compounds which were isolated from heated glucose including aldehydes, ketones, acids, furans, alcohols, and various aromatic compounds. The chemical composition of caramel was extremely complex and was imperfectly understood.

## Summary

The Maillard reaction is a non enzymatic browning reaction involving the reaction between a reducing sugar and an amino acid. A review of literature showed that amino acids, particularly lysine and the sulphur containing amino acids were often found in food products that underwent heating and the Maillard reaction played an important role in the food industry, both for its positive aspects and negative aspects. Cereal products were affected very easily particularly if reducing sugars were present. The browned cereal products when fed to animals may have deleterious effects. The use of commercially available enteral and parenteral solutions have shown to have undergone Maillard reaction and have Maillard products. Meat products were more resistant to Maillard reaction, due to the low carbohydrates present in them. Some of the positive aspects of Maillard reaction would include the appetizing aromas and flavours produced in baked products, roasting of nuts and cocoa and coffee beans and maderizing of wine. In dairy products, especially milk, the nutritional damage caused due to heating was seen to be inoffensive.

# CHAPTER III

## METHODS AND PROCEDURES

The research was designed to determine whether browning of feeds composed of four different sugars affected the growth of chicks. Appropriate statistical procedures were used to analyze the data.

### Research Design

In this experiment, chicks were used as an assay animal. A randomization procedure was used to assign the chicks and the treatments to the pens. The initial experimental design plan was to use the randomized block design. Due to the limited number and placement of pens available, the experimental design was changed to a completely randomized design. The dependent variable of this study was the chick weight gains, and the independent variable was the feed treatment.

### Population and Sample

The project to study the growth rate of chicks fed browned and unbrowned feeds was funded by the College of Home Economics, Oklahoma State University. The sample population for this study was 144 seven-day-old chicks placed in experimental units of six chicks per experimental unit, which was the pen. The randomly chosen chicks were mixed sex with weights ranging between 65 gms to 100 gms.

## Preparation of the Feed

Four feeds each with a different sugar were prepared. The sugars (sucrose, fructose, dextrose, or cerelose) were combined with flour, egg solids, oil, and yeast and mixed throughly using a Hobart mixer. Half of each of the four feeds were browned to a uniform temperature of 110° C + - 3° C on a shallow (24 x 17 x 1) baking sheet in a commercial deck oven. In order to ensure uniform browning, the feed was removed from the oven every five minutes, stirred throughly and then returned to the oven with this repeated until the desired temperature and colour was achieved. After browning, the mixtures were immediately spread on long counters to facilitate rapid cooling. When the feeds were cooled vitamins and minerals were mixed into the feed using a small Hobart mixer.

Sucrose and fructose were purchased from a local grocery. The J. B. Baker brand U.S.P. Dextrose was obtained from the University Chemistry supply room. The cerelose, vitamin and mineral mixes and egg solids were provided by the Animal Science Department, Oklahoma State University. Yeast was purchased from the University Food Service. The composition of the feed was that used in an earlier study done at Oklahoma State University by Knight and Hanson (5). The composition of the feed is shown on Table III. The vitamin and mineral composition are shown on Table IV and V.

## Assigning Treatment to Pens

Three ten pen batteries were used for the entire study, although not all of the pens in each battery could be used. In the first

TABLE III

MINERAL COMPOSITION OF THE FEED
TEKLAD TEST DIET 73007

| Mineral | gm kg |
|---|---|
| Calcium carbonate | 55.94 |
| Calcium phosphate, tribasic | 522.102 |
| Calcium phosphate, dibasic | 167.819 |
| Sodium chloride | 164.819 |
| Magnesium sulphate | 65.263 |
| Ferric citrate | 9.323 |
| Zinc cabonate | 1.865 |
| Cupric sulphate | 0.373 |
| Boric acid | 0.168 |
| Sodium molybdate | 0.168 |
| Potassium iodide | 0.746 |
| Cobalt sulphate | 0.019 |
| Sodium selenite | 0.004 |

TABLE IV

VITAMIN COMPOSITION OF THE FEED
TEKLAD TEST DIET 78475

| Vitamin | gm kg |
|---|---|
| Thiamin HCl | 2.2 |
| Riboflavin | 2.2 |
| Calcium pantothenate | 6.6 |
| Niacin | 10.0 |
| Pyridoxine HCl | 2.2 |
| Folic acid | 0.2 |
| Biotin | 0.04 |
| Vitamin B 12 (0.1% trituration in mannitol) | 3.0 |
| Menadione sodium bisulphite | 10.0 |
| Dry vitamin A palmitate (500,000 u gm) | 4.0 |

TABLE IV (Continued)

| Vitamin | gm kg |
|---|---|
| Vitamin D 3 in VFT casein (3000 u gm) | 66.0 |
| Dry vitamin E acetate (500 u gm) | 24.0 |
| Choline dihydrogen citrate | 350.0 |
| Corn starch | 519.56 |

TABLE V

COMPOSITION OF THE FEED

| Ingredients | Percentage |
|---|---|
| Eggs | 26.43 |
| Flour | 47.80 |
| Sugar | 10.00 |
| Yeast | 5.00 |
| Oil | 5.00 |
| Vitamins | 0.40 |
| Mineral salts | 5.37 |
| TOTAL | 100.00 |

battery, six pens were used, and in the third only eight pens were used. (The pen placement and treatments within the batteries can be seen in Appendix A). The eight treatments were randomly assigned to the pens, and each treatment was replicated three times. The eight treatments were:

1. Cerelose Browned (CB)
2. Cerelose Unbrowned (CUB)
3. Dextrose Browned (DB)
4. Dextrose Unbrowned (DUB)
5. Fructose Browned (FB)
6. Fructose Unbrowned (FUB)
7. Sucrose Browned (SB)
8. Sucrose Unbrowned (SUB)

Random numbers were chosen using a random number table to match the pens with the treatments. Individual chicks were also randomly assigned to the pens. Three pens were used for each treatment, and each pen contained six chicks.

## Data Collection

In order to monitor the growth rate of the chicks receiving the treatment rations, the weight of the chicks were recorded on days 4, 7, and 10. Water and feed were provided ad libitum. The pen was the experimental unit, so amounts of feed consumed daily per pen were recorded. Each pen had its own feeder which was weighed, and 1300 gm of the feed was added at the beginning of the experiment. The feeders were then weighed daily. This weight was recorded, and the feed in each feeder again brought to 1300 gm. The difference was used to determine the total amount of feed consumed by the chicks in each pen. The feeders were weighed during the same time period each day (5:00 p.m. to 6:00 p.m.). After day 3, the feeder weights were increased to 1500 gm to allow for increasing feed intake of the chicks. An upright single beam balance was used to determine the

weight of the feeders. The balance was caliberated daily. The chicks were wing baned and weighed individually, on the day the experiment began and weighed again at the end of the experiment. On the other weighing days the average weight of the chicks per pen was determined.

Amino Acid Analysis

The amino acid contents of the feed samples were obtained using a Beckman Automatic Amino Acid Analyzer 120B (Beckman Instruments, Inc., Spinco Division, Palo Alto, California, U.S.A.), this fully automatic ion exchange column procedure was performed by the Animal Science Department, Oklahoma State University. The values of the Amino Acids in the different feeds are shown in Appendix B.

# CHAPTER IV

## RESULTS AND DISCUSSION

This chick assay was undertaken to study the growth responses of chicks to be oven-browned feed. The hypotheses listed in Chapter I were tested using analysis of variance, followed by F-tests and Duncan's multiple range tests.

### Growth Responses of Chicks

The initial average weight of the chicks per treatment ranged was 79 +/- 5 gms. The final average weight per treatment ranged from 95.72 gms (chicks on browned fructose feed) to 156.99 gms (chicks on the browned sucrose feed). Chicks on the browned ration that contained fructose sugar consistenly weighed less than the chicks on the other treatments. Chicks on the dextrose browned ration had a mean final weight more than the browned fructose ration chicks but less than the other treatments. Mean chick weights on the browned ration with Cerelose brand glucose sugar were larger at the end of the study than the browned dextrose chicks. Dextrose and Cerelose, which have the same molecular formula, did not show the same responses in the growth of chicks. For all of the monosaccharide sugars, the unbrowned feeds produced greater final mean chick weights than the browned feeds. However, in the treatments using sucrose, the

browned feed produced a final mean chick weight greater than the unbrowned feed. The mean chick weight on the browned sucrose feed was the greatest of all the treatments in the study. Figures 4 and 5 shows the chicks representative of the pens having the largest and smallest mean weights.

Table VI shows the Duncan's multiple range test performed on the mean chick weights per treatment for the final day and shows that the chicks fed the fructose sugar were significantly smaller than the chicks on the other treatments ($p=0.0417$, Appendix C). In this study, as in the previous work done by Knight and Hanson (5), there appeared to be more nutrient binding associated with browning a feed containing the U.S.P. dextrose (J. B. Baker brand) glucose than with the cerelose brand (Corn Products Co.,) glucose. These are supposedly to have both been glucose monohydrate and did, upon moisture analysis in the previous study, show the same water content. It was not known whether the isomeric forms of these sugars was the same, and this was not determined as a part of this study. Pictures contrasting the chicks on the various treatments at the end of the study are shown in Figures 6 through 9.

## Average Weight Gain of Chicks

The average weight per chick, per pen, was obtained on days 1, 4, 7, and 10. The average weight gain per treatment over different intervals of days was taken into consideration to see the effect of treatment on the average weight gain on chicks for the different treatments and given intervals of days.

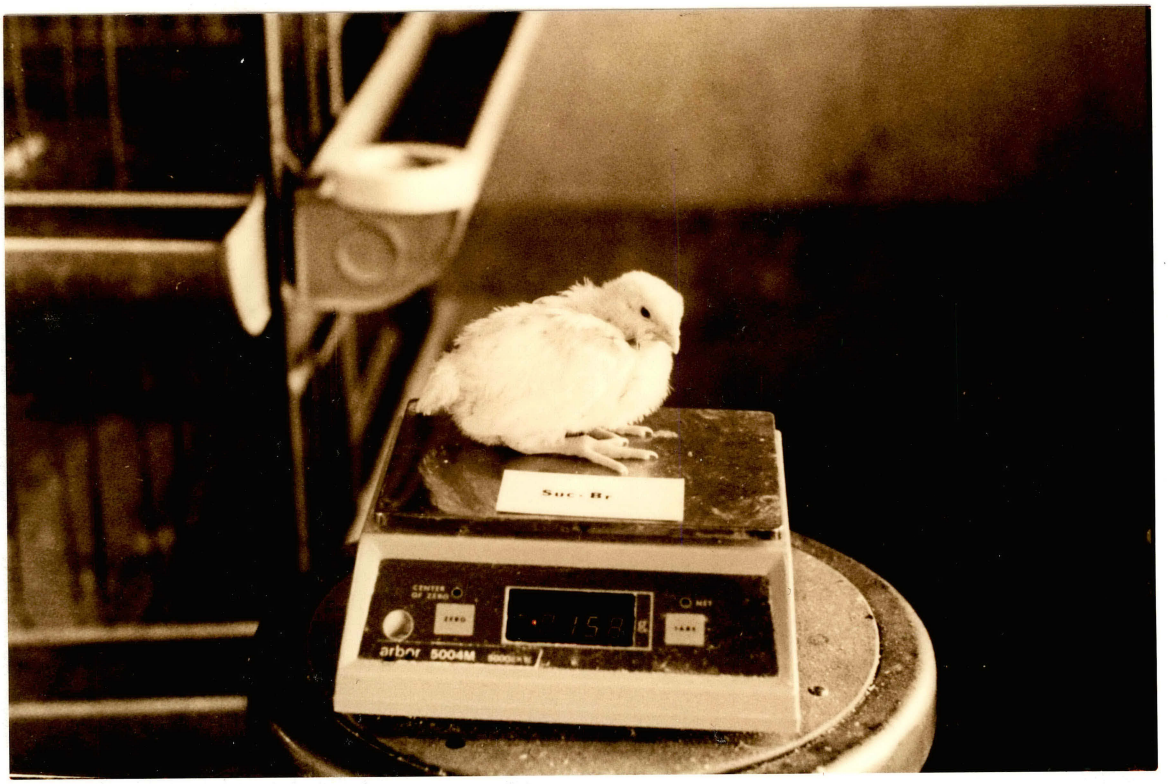



Figure 4. Representative Chick from Treatment Sucrose Browned, Having the Largest Mean Weight on the Final Day of the Study


Figure 5. Representative Chick from Treatment Fructose Browned Having the Smallest Mean Weight on the Final Day of the Study


Figure 6. Representative Chicks from Treatments Cerelose Unbrowned and Cerelose Browned on the Final Day of the Study


Figure 7. Representative Chicks from Treatments Dextrose Unbrowned and Dextrose Browned on the Final Day of the Study


Figure 8. Representative Chicks from Treatments Fructose Unbrowned and Fructose Browned on the Final Day of the Study


Figure 9. Representative Chicks from Treatments Sucrose Unbrowned and Sucrose Browned on the Final Day of the Study

TABLE VI

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN WEIGHT OF CHICKS PER TREATMENT ON FINAL DAY

| Treatment | Mean Weight of Chicks on Final Day (gms) | Duncan's Grouping |
|---|---|---|
| SB | 156.99 | A |
| DUB | 151.39 | B A |
| CB | 147.73 | B A |
| SUB | 147.13 | B A |
| FUB | 145.89 | B A |
| CUB | 144.09 | B A |
| DB | 112.50 | B C |
| FB | 95.72 | C |

(In the above table, means with the same letter are not significantly different.)

Weight Gain of Chicks Between Day 1 and Day 4. The average daily gain of chicks per treatment between Day 1 and Day 4, ranged from 11.50 gms to 10.11 gms. Weights of chicks on the unbrowned ration containing the dextrose sugar increased the most (57.34 gms) during this 3 day period, and chicks on the unbrowned ration with sucrose gained the least weight, 34.49 gms. Chicks on the browned ration containing sucrose sugar gained the second most weight (55.64 gms), and chicks on the browned rations with dextrose or fructose gained the third and least weights (37.36 gms and 37.01 gms). The chicks on the unbrowned ration containing dextrose gained approximately 20 gms more than their browned feed counterparts. However, there were no

statistically significant differences among the weight gain of chicks between Day 1 and Day 4 (p=.2012), due to treatments. The Duncan's multiple range test showing the significant groupings and the total mean weight between Day 1 and Day 4 is shown on Table VII.

TABLE VII

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN WEIGHT GAIN OF CHICKS PER TREATMENT BETWEEN DAY 1 AND DAY 4

| Treatment | Mean Weight Gain Of Chicks Between Day 1 and Day 4 (gms) | Duncan's Grouping |
|---|---|---|
| DUB | 57.34 | A |
| SB | 55.64 | A |
| CUB | 55.60 | A |
| CB | 47.16 | A |
| FUB | 47.08 | A |
| DB | 37.36 | A |
| FB | 37.01 | A |
| SUB | 34.49 | A |

Weight Gain of Chicks Between Day 1 and Day 7. The average daily gain of chicks per treatment between Day 1 and Day 7 ranged from an average daily gain of 0.93 gms. to 6.25 gms. leading to total per chick gains from 5.61 gms (DB) to 37.40 gms (DUB). This gain was lower than the average weight gain of chicks per treatment between Days 1 and 4. Significant differences in weight gain between Day 1

and Day 7 ($p=0.0161$, Appendix A), due to treatment were seen. In this six day time interval, the weight gain of chicks on the unbrowned rations containing the dextrose, cerelose, and fructose sugars were significantly higher than the average weight gain of chicks on the browned rations containing the dextrose and fructose sugars. The Duncan's multiple range test showing the signficant groupings and the total mean weight gains between Day 1 and Day 7 is shown on Table VIII.

TABLE VIII

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN WEIGHT GAIN OF CHICKS PER TREATMENT BETWEEN DAY 1 AND DAY 7

| Treatment | Mean Weight Gain of Chicks Between Day 1 and Day 7 (gms) | Duncan's Grouping |
|---|---|---|
| DUB | 37.40 | A |
| CUB | 27.29 | A |
| FUB | 27.29 | A |
| SB | 25.65 | B A |
| CB | 25.23 | B A |
| SUB | 20.83 | B A C |
| FB | 7.20 | B C |
| DB | 5.61 | C |

(In the above table, means with the same letters are not significantly different.)

Weight Gain of Chicks Between Day 1 and Day 10. The average

daily weight gain of chicks for each treatment, between Day 1 and Day 10, ranged from 1.86 gms (browned fructose) to 8.59 gms (unbrowned dextrose), with total gain over the entire 9 day period ranging from 16.77 gms (browned fructose) to 77.29 gms (unbrowned dextrose). Significant differences in weight gain of chicks between Day 1 and Day 10 that was attributable to treatments was seen ($p=0.0088$, Appendix A). The mean weight gains of chicks fed the browned feed containing fructose and dextrose were significantly less than for the other treatments as is shown on Table IX. The chicks receiving the Cerelose unbrowned treatment gained the most weight but not significantly more than the chicks receiving the other unbrowned treatments or the sucrose and cerelose browned treatments as seen on Table IX.

TABLE IX

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN WEIGHT GAIN OF CHICKS PER TREATMENT BETWEEN DAY 1 and DAY 10

| Treatment | Mean Weight Gain of Chicks Between Day 1 and Day 10 (gms) | Duncan's Grouping |
|---|---|---|
| DUB | 77.29 | A |
| SB | 75.30 | A |
| CB | 70.50 | A |
| SUB | 65.36 | A |
| FUB | 63.92 | A |
| CUB | 63.76 | A |
| DB | 29.11 | B |
| FB | 16.77 | B |

(In the above, means with the same letters are not significantly diff.)

Weight Gains of Chicks Between Day 4 and Day 10. Significant differences in the weight gain of chicks between Day 4 and Day 10, due to the treatments were seen ($p=0.0051$, Appendix C), see Table X.

TABLE X

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN WEIGHT GAIN OF CHICKS BETWEEN DAY 4 AND DAY 10

| Treatment | Mean Weight Gain of Chicks Between Day 4 and Day 10 (gms) | Duncan's Grouping |
|---|---|---|
| SUB | 30.84 | A |
| CB | 23.34 | A |
| DUB | 19.95 | A |
| SB | 19.66 | A |
| FUB | 16.83 | A |
| CUB | 8.16 | B A |
| DB | -8.25 | B C |
| FB | -20.25 | C |

(In the above table, means with the same letters are not significantly different.)

Chicks fed the browned ration containing dextrose and fructose sugar showed a negative weight gain during this period of time. The weight gains of chicks fed these two rations between Day 7 and Day 10 (Table XII) did not show a weight loss as they did between Day 4 and Day 10 nor, between Day 7 and Day 10. From Table XI it can be seen

that chicks on the unbrowned ration containing sucrose gained the most weight during this period.

TABLE XI

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN WEIGHT GAIN OF CHICKS BETWEEN DAY 7 AND DAY 10

| Treatment | Mean Weight Gain of Chicks Between Day 7 and Day 10 (gms) | Duncan's Grouping |
|---|---|---|
| CB | 45.27 | A |
| SUB | 44.53 | A |
| DUB | 39.89 | B A |
| SB | 38.72 | B A |
| FUB | 36.62 | B A |
| CUB | 36.47 | B A |
| DB | 18.34 | B C |
| FB | 9.56 | C |

(In the above table, means with the same letters are not significantly different.)

Weight Gain of Chicks Between Day 7 and Day 10. The average weight gain of chicks between Day 7 and Day 10 ranged from 9.56 gms (fructose browned) to 45.27 gms (cerelose browned) for an average daily gain ranging from 3.51 gms (fructose browned) to 15.09 gms (cerelose browned) over this 3 day period. The chicks fed the fructose browned feed gained significantly less weight than the chicks receiving the other treatments ($p=.0315$, Appendix C, Table XI).

## Feed Intake

The amount of feed consumed by the chicks was recorded daily. The average intake of feed per pen, per treatment, ranged from 20 gms on the first day to 265 gms on the final day. Analysis of variance followed by F-tests and Duncan's multiple range tests were used to test for significant differences on the mean intake of feed by the chicks due to treatments. On Day 1, the chicks fed the unbrowned ration containing sucrose sugar did not eat anything. However, chicks on the browned feed containing sucrose consumed the largest amount of feed, which was 48.33 gms. There were significant differences in the intake of feed by the chicks that could be attributed to treatments (-0.0001). The Duncan's multiple range test grouping is shown on Table XII.

TABLE XII

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN FEED INTAKE OF CHICKS BY PEN ON DAY 1

| Treatment | Mean Feed Intake Per Pen On Day 1 (gms) | Duncan's Grouping |
|---|---|---|
| SB | 48.33 | A |
| FUB | 46.67 | A |
| CB | 44.67 | A |
| DUB | 35.00 | B A |
| CUB | 25.00 | B C |
| FB | 18.33 | B C |
| DB | 8.33 | D C |
| SUB | 00.00 | D |

In the table, means with the same letters are not significantly different.

Significant differences in the intake of feed by chicks due to treatments was seen on Day 4 (p=0.0001), 5 (p=0.0149), and the last two days (p=0.0485). Duncan's multiple range test grouping for the feed intake on these days is shown on Tables XIII, XIV, and XV. The average intake of feed in the three pens per treatment during the last two days ranged from 91.83 gms (fructose browned) to 260.33 gms (cerelose unbrowned). From the Duncan's multiple range test grouping for these last two days it can be seen that the chicks on the browned

TABLE XIII

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN FEED INTAKE OF CHICKS BY PEN ON DAY 4

| Treatment | Mean Feed Intake Per Pen On Day 4 (gms) | Duncan's Grouping |
|---|---|---|
| CUB | 148.74 | A |
| DUB | 148.00 | A |
| FUB | 135.00 | B A |
| SUB | 106.67 | B |
| CB | 95.00 | C |
| DB | 90.67 | C |
| SB | 88.67 | C |
| FB | 84.67 | C |

(In the above table, means with the same letters are not significantly different.)

rations containing the dextrose and fructose sugars ate less feed than those on the other treatments; although the browned dextrose feed intakes were not significantly less than the other treatments.

TABLE XIV

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN FEED INTAKE OF CHICKS BY PEN ON DAY 5

| Treatment | Mean Feed Intake Per Pen On day 5 (gms) | Duncan's Grouping |
|---|---|---|
| SB | 214.00 | A |
| FUB | 179.33 | B A |
| CUB | 155.67 | B A C |
| CB | 155.00 | B A C |
| DUB | 131.00 | B A C D |
| SUB | 118.00 | B C D |
| FB | 75.00 | C D |
| DB | 64.00 | D |

(In the above table, means with the same letters are not significantly different.)

Feed Intake and Growth Response

The weight gain of chicks on the browned feed containing the dextrose and fructose sugars were in proportion to the amount of feed consumed by these chicks. As can be seen on Tables IX - XV, the chicks on the browned feeds containing fructose and dextrose sugars consumed the least feed and gained the least weight. As might be

TABLE XV

THE DUNCAN MULTIPLE RANGE TEST FOR MEAN FEED INTAKE ON CHICKS BY PEN ON THE FINAL 2 DAYS

| Treatment | Mean Feed Intake Per Pen On The Final 2 Days (gms) | Duncan's Grouping |
|---|---|---|
| CUB | 260.33 | A |
| SB | 245.33 | A |
| SUB | 213.67 | A |
| CB | 202.83 | A |
| FUB | 193.00 | A |
| DUB | 192.00 | A |
| DB | 177.50 | B A |
| FB | 91.83 | B |

(In the above table, means with the same letters are not significantly different.)

expected, the chicks that ate the most tended to gain the most with no significant differences in the final feed intake or total weight gains among any of the unbrowned feed or the browned sucrose and cerelose feed. The feed efficiencies of the different treatments is shown on Table XVI. A picture of the different feeds is shown in Figure 10.

## Effect of Battery on the Feed Intake and Growth Response of Chicks

There appeared to be differences in feed intakes and weight gains of the chicks due to Battery and side of Battery. Analysis of variance was used to determine whether the differences were significant.


Figure 10. Feed Samples from all Treatments Contrasting Browned and Unbrowned Feed for Each Sugar

At the end of the study the mean chick weight was Battery No. 1, 126.83 gms, Battery No. 2, 169.27 gms, and Battery No. 3, 129.04 gms (Appendix A).

TABLE XVI

FEED EFFICIENCY

| Treatment | Average Daily Feed Intake (gms) | Average Weight Gain (gms) | Feed Efficiency |
|---|---|---|---|
| CB | 190.67 | 58.88 | 1.87 |
| CUB | 219.40 | 59.68 | 3.68 |
| DB | 38.37 | 33.23 | 1.06 |
| DUB | 102.00 | 43.23 | 2.36 |
| FB | 28.06 | 26.89 | 1.04 |
| FUB | 120.00 | 48.00 | 2.50 |
| SB | 143.47 | 50.50 | 2.84 |
| SUB | 143.70 | 65.47 | 2.19 |

These differences were statistically significant ($p=0.0098$, Appendix C). Significant differences in the weight gain of chicks were seen between the first day and the last day ($p=0.0288$, Appendix C). The mean chick weight gain was Battery No. 1, 44.96 gms, in Battery No. 2, 83.93 gms, and in Battery No. 3, 58.12 gms (Appendix A).

Regarding feed intakes, significant differences were seen due to battery ($p=0.0015$, Appendix C) on the final two days. Battery No. 2 had more number of chicks than the other two batteries and

had a higher total feed consumption, but Battery No. 1 showed the highest intake of feed per chick. The total feed intake and feed intake per chick was higher for side A than for side B for all three batteries. The total feed intakes and the per chick intakes for each battery and for both sides of each battery, along with the corresponding weight gains, are shown in Appendix A.

From these findings it appears that Battery No. 3 (which was closest to the entrance and the water faucet) had the lowest feed intake. The chicks in this particular battery could have been easily distracted resulting in a poor intake of the feed.

## Amino Acid (Lysine) Content of the Feed

The amounts of lysine present in the browned feeds was less than the unbrowned counterparts for all sugars. Also, there was a difference in the amino acid within the browned treatment due to the sugar used in the feed. The lysine contents of the feeds tended to correspond to the chick weight gains and levels of feed intake. The feeds that suffered the most amino acid loss were browner in colour.

Significant differences were found in the amounts of lysine in the feed due to treatments ($p=0.0116$, $sd=0.002$). Table XVII shows the mean lysine content of the feeds. The feed intake showed that the chicks tended to consume more of the unbrowned feed than the browned feed, so that the chicks in general ate less and grew less on the browned feed. This same decrease in the intake of feed was seen in the study done by Knight and Hanson (5). When they added lysine to the browned feed, the chicks which otherwise did not eat the feed started consuming it and gained weight. Therefore, it would appear

TABLE XVII

MEAN LYSINE CONTENT OF THE FEED

| Treatment | Mean Lysine Content |
|---|---|
| SB | 0.9135 |
| SUB | 0.9872 |
| DB | 0.7961 |
| DUB | 0.9458 |
| FB | 0.7142 |
| FUB | 0.9697 |
| CB | 0.8709 |
| CUB | 0.9672 |

that the reduction of lysine and the other amino acids due to browning resulted in the chicks eating less and gaining less.

Growth Response and Amino Acid (Lysine) Content of the Feed

The growth responses of the chicks compared with the amino acid content of the feeds are shown on Table XVIII. This table contrasts the average chick weight gain on the unbrowned feed treatments and the four browned treatments with the lysine content of the feeds (determined by amino acid analysis). The results of the amino acid analysis done in duplicate are included in Appendix B.

From the growth responses it appeared that nutrient binding caused by browning was greatest in the feeds containing the reducing sugars dextrose and fructose. Also browned feeds containing these sugars retained less lysine than their unbrowned counterparts.

TABLE XVIII

CONTRAST BETWEEN AVERAGE FEED INTAKE
AVERAGE WEIGHT GAIN OF CHICKS AND
LYSINE CONTENT OF THE FEED

| Treatment | Lysine Content of the Feed (gm/100 gm) | Average Feed Intake Of Chicks (gms) | Average Weight Gain of Chicks (gms) |
|---|---|---|---|
| SUB | 0.9872 | 95.02 | 65.36 |
| FUB | 0.9697 | 125.59 | 63.92 |
| CUB | 0.9692 | 133.19 | 63.76 |
| DUB | 0.9458 | 120.75 | 77.29 |
| SB | 0.9135 | 143.45 | 75.30 |
| CB | 0.8709 | 109.83 | 70.50 |
| DB | 0.7961 | 88.43 | 29.11 |
| FB | 0.7142 | 65.23 | 16.77 |

Sucrose, a non reducing sugar did not show the same degree of nutrient binding. Cerelose, a reducing sugar, resulted in better growth and less lysine loss than the two other reducing sugars used in this study. It is reasonable to say that lysine, which is essential for both man and chicks was partially bound in these two feeds, as reflected by the growth pattern of the chicks and the amino acid analysis. It has to be studied whether, the structural formula of glucose (cerelose) was different from the other glucose (U.S.P. dextrose, J. B. Baker brand).

# CHAPTER V

## SUMMARY AND RECOMMENDATIONS

The Maillard reaction plays an important role in food industry, both for its positive aspects and negative aspects. A review of the literature has shown that amino acids particularly, lysine are often bound in food products that undergo the Maillard reaction. Lysine in cereal products is particularly affected by the Maillard reaction. Research done at Oklahoma State University by Knight and Hanson (5) using bread flour, yeast, eggs, oil, and glucose, in a chick feeding experiment showed a very slow growth in the chicks that received a browned feed.

The purpose of this study was to investigate the effect of non enzymatic browning of chick feeds prepared with different sugars on the growth rate of chicks. The sugars used were sucrose, fructose, and two different sources of glucoses (U.S.P. J. B. Baker brand dextrose obtained from a chemistry supply house, and Cerelose, manufactured by Corn Products Co.,).

Each of the four sugars were combined with flour, dried eggs, yeast, and oil. Half of each feed was browned to a uniform temperature of 100° C + 3° C in a institutional deck oven (about 15 minutes). For the eight different treatments three replicates per treatment was done. There were six, seven-day-old, chicks per pen, and the

served as the experimental unit. A completely randomized design was used to assign both the chicks and the treatments to the pens. One hundred and forty-four chicks were used in this chick assay.

The chicks were wing baned and weighed individually at the start of the experiment and weighed again on the final day of the experiment. The experiment ran for ten days. Also the average weight of chicks per pen was determined on days 4, 7, and 10. Feed and water were provided ad libitum. The amount of feed consumed was determined daily by weighing the feeders.

The following findings resulted from this study:

1. The mean weight gain of chicks on the browned feed was lower than on the unbrowned feed, and of the browned feeds those prepared with fructose and dextrose produced total per chick mean weight gains of only 26.94 gms and 33.24 gms respectively.

2. The total mean intake of feed per chick on the browned feed with fructose and dextrose sugars was low, 65.23 gms and 88.43 gms respectively. Statistically significant difference in the mean intake of feed due to treatments was seen ($p=0.0369$).

3. The lysine content of the browned feed for all the sugars was less than their unbrowned counterparts (Table XVII), and the lysine contents of the feeds was correlated to the weight gain of the chicks ($r=0.9652$, $n=8$).

4. The chicks on the browned feed containing fructose sugar consumed the least amount of feed 65.23 gms and gained the least weight 16.77 gms, and this feed had the lowest amount of lysine (.7142 gms/100 gms).

## Testing the Hypotheses

Three hypotheses were stated in this study. Analyses of variance followed by Duncan's Multiple Range Tests were performed to test the hypotheses. Although there were no significant differences in the feed intake of chicks, growth rate of chicks, and lysine content of the feed due to sugars in the unbrowned feed, significant differences were seen in the browned feed in feed intake by chicks, growth rate of chicks and the lysine content of feed due to sugars used; therefore, all of the three hypotheses were rejected.

## Recommendations for Further Research

1. Because of the arrangement of the pens available, the study employed a completely randomized design. However, a randomized block design would have given more precision and would have simplified analysis. A comparison of the results of this study with one done following a randomized block design is recommended.

2. A similar study should be done using albino rats or guinea pigs in order to more nearly predict responses in human beings since their physiology is more similar to man than are chicks.

3. The bread content used should be baked into loaves and the effect of a feed made of the brumb versus the crust on the growth of animals should be studied.

4. The experiment should be repeated under more controlled conditions to remove the effect of ambient temperatures, and pen placements, and concurrent studies.

5. Chicks should be allowed to grow on the treatment feeds

until fully grown and the chickens sacrificed to see if the Maillard products affected the flavour of the mean or damaged the liver or kidneys.

6. It should be determined if stereoisomers of glucose have the same effect on browning and whether the difference between the two glucoses used in this study were due to their being different stereoisomers.

BIBLIOGRAPHY


1. Gordon, G. B., Spencer, M., and Cameron A. G.: Food Science. Pergamon Press, New York, 1977.

2. Maillard, L. C.: Action des acides amines surless. Sucres formation des melanoides parvoie, methodique. C. R. Hebd Seances Acad Sci. 154:66, 1912.

3. Patton, A. R.: Present status of heat processing damage to protein foods. Nutr Rev. 8:193, 1950.

4. Kawamura, S.: Seventy years of the Maillard reaction: In the Maillard Reaction in Foods and Nutrition. Am Chem Soc. Washington, D.C. 1983.

5. Knight, S., and Hanson, C.: Unpublished Report. Oklahoma State University. 1982.

6. Kimiager, M., Lee, T. C., and Chichester, C. O." Chronic feeding effects of Maillard browned protein to rats: In FASEB Proceedings, 62 Annual Meeting, Atlantic City, New Jersey, 1980.

7. Fisher, H.: Chick as an assay animal: In Nutrients in Processed Foods: Proteins, Publishing Science Group, Inc., Action, MA, 1974.

8. Robinson, C. H. and Lawler, M. R.: Normal and therapeutic nutrition. MacMillan Publishing Co., Inc., New York, 1977.

9. Reed, P. B.: Nutrition an applied science. West Publishing Co., St. Paul, MN, 1980.

10. Lang, K.: Influence of cooking on foodstuffs. World Rev Nutr Dietet. 12:266, 1970.

11. Baum, S. J.: Introduction to organic and biological chemistry. MacMillan Publishing Co., Inc., New York, 1978.

12. Kawamura, S.: Sixty years of the Maillard reaction. Shokuhin Kaihatsu. 7(12):64, 1972.

13. Maillard, L. C.: Condensation des acides amines en presence de la glycine; cycloglycylglycine et polypeptides. C. R. Hebd Seances Acad Sci. 153:1078, 1911.

14. Ling, A. R.: Malting. J Inst Brew. 14:494, 1918.

15. Pictet, A., Chou, T. Q.: La formation des bases pyridiques et isoquinoleiques a partir de la caseine. C. R. Hebd Seances Acad Sci. 162:127, 1916.

16. Reynolds, T. H.: Chemistry of nonenzymatic browning II. Adv Food Res. 14:167, 1965.

17. Thompson, J. B.: A browning reaction involving copper protein. In symposium on copper metabolism. Johns Hopkins Press, 1950.

18. Barnes, H. K, Kaufman, C. W.: Industrial aspects of browning reaction. Ind Eng Chem. 39:1167, 1947.

19. Litner, C. J.: Ueber farbe und aromabildung im darsmalz Z Gesamte Brauwes. 35:545, 1912.

20. Ruckdeschel, W.: Uever melanoidine und chi vokommen im Darrmalz. Z Gesamte Brauwes. 37:430, 1914.

21. Montogmery, M. W. and Day, E. A.: Aldehyde amine condensation reaction: a possible fate of carbonyl in foods. J Food Sci. 30:828, 1965.

22. Kwon, T. W., Menzel, D. B., and Olcott, H.S.: Reactivity of malonaldehyde with food constituents. J Food Sci. 30:808, 1965.

23. Maillard, L. C.: Reaction generale des acides amines sur les sucres ses consequences biologiques. C. R. Soc Biol, 72:599, 1912.

24. Hodge, J. E.: Chemistry of browning reaction in model systems. J Agric Food Chem. 1:928, 1953.

25. Adrian J.: Nutritional and physiological consequences of the Maillard reaction. World Rev Nutr Dietet. 19:71, 1972.

26. Knipfel, J. E.: Nitrogen and energy availabilities in foods feeds subjected to heating. Prog Fd Nutr Sci. 5:177, 1981.

27. Knipfel, J. E., Botting, H. C. and McLaughlan, J. M.: Nutritional quality of several proteins as affected by heating in the presence of carbohydrates: In Protein Nutritional quality of foods and feeds. M. Friedman ed., Mercell Dekker Inc., New York, 1975.

28. Finot, P. A. and Magenat, E.: Metabolic transit of early and advanced Maillard products. Prog Fd Nutr Sci. 5:193, 1981.

29. Horikishi, M. and Gomyo, T.: Precipitation of protein in the presence of melanoidin. Agric Biol Chem. 40:1531, 1976.

30. Fahey, G. C., Williams, J. E. and Mcharen, G. A.: Influence of molasses lignin-hemicellulose fractions in rat nutrition. J Nutr. 106:1447, 1976.

31. Lee, C. M., Chichester, C. O. and Lee, T. C.: Physiological consequences of browned food products. Proc Int Cong Food Sci Technol. 4:587, 1977.

32. Homa. S. and Fujimuki, T.: Growth responses of rats fed a diet containing nondialzable melanoidin. Prog Fd Nutr Sci. 5:209, 1981.

33. Nair, B. M., Oste, R. Asp, N. G. and Pernemalm, P. A.: Absorption and distribution of C 14 - glucose lysine reaction mixture in the rat. Prog Fd Nutr Sci. 5:217, 1981.

34. Erbersdobler, H. F., Von Wangenheim, B. and Hanichem, T.: Adverse effects of Maillard products - especially of fructose lysine - in the organism. Abstracts of the fifth international congress in nutrition. Rio de Janero, 1978.

35. Horikoshi, M., Ohmura, M., Gomyo, T., Kuwabara, Y. and Ueda, S.: Effects of browning products on the intestinal microflora of the rat. Prog Fd Nutr Sci. 5:223, 1981.

36. Rosa, L. D. and Gilliland, T.: Masters Thesis. Oklahoma State University. 1983.

37. Lee, T. C., Kimiager, H., Pintauro, S. J., Chichester, C. V.: Physiological and safety aspects of Maillard browning of foods. Prog Fd Nutr Sci. 5:243, 1981.

38. Freeman, J. B., Stegink, L. D., Meyer, P. D., Fry, L. K. and Den Bester, L.: Excessive urinary zinc losses during parenteral alimentation. J Surg Res. 18:463, 1975.

39. Stegink, L. D., Sheperd, J. A., Fry, L. K. and Filer, L. J., Jr.: Sugar-amino acid complexes in parenteral alimentation. Pediat Res. 8:396, 1974.

40. Berrens, L.: The chemical classification of atopic allergens an attempt at integration. Int Arch Allerg. 41:186, 1971.

41. Wolinsky, I. and Brinkman, G. L.: Carcinogenicity of a lysine deficient diet. Fed Proc. 35:782, 1976.

42. Porter, J. W. G.: Review of the progress of dairy science: Nutritive value of milk and milk products. J Dairy Res. 31:201, 1964.

43. Hurrel, R. F. and Carpenter, K. J.: The estimation of available lysine in foodstuffs after Maillard reaction. Prog Fd Nutr Sci. 5:159, 1981.

44. Fink, H., Schbe, I. and Ruge, U.: Uber ernabrungs physiologische veranderungen der milk bein technischen troknen. Z Naturforsch. 13 B: 610. 1958.

45. Ferrando, R.: Effects biologiques du chauffage de la viande en presence d'hesosamine (d'glucosamine) C R Acad Sci. 257:1161, 1963.

46. Adrian, J.: Nutritional and physiological consequences of the Maillard reaction. World Rev Nutr Dietet. 19:71, 1974.

47. Sipple, L. H. and McNutt, K. W.: Sugars in Nutrition. Academic Press. New York. 1974.

48. U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, 1972.

49. Rohan, T. A. and Stewart, T. J.: The precursors of chocolate aroma. J Food Sci. 31:202, 1966.

50. Linko, Y. Y. and Johnson, T. A.: Changes in amino acids and formation of carbonyl compounds during baking. J Agric Food Chem. 11:150, 1963.

51. Greaves, G. and Morgan, A. F.: Nutritive value of raw and heated casein with and without added amino acids. Proc Soc Exp Biol Med. 31:506, 1933.

52. Labuza, T. P., Warren, R. and Warmbier, H. C.: The physical aspects with respect to water activity and non-enzymatic browning: In Nutritional biochemical and chemical consequences of protein cross-linking. Adv Med Biol. 86B:379, 1977.

53. Miller, E. L., Carpenter, K. J. and Milner, C. K.: Chemical and nutritional changes in heated cod muscles. Br J Nutr. 19:547, 1965.

54. Smith, R. E. and Scott, H. M.: Biological evaluation of fishmeal proteins as sources of amino acids for the growing chick. Poul Sci. 44:401, 1965.

55. Lea, C. H., Parr, L. J. and Carpenter, K. J.: Chemical and nutritional changes in stored herring meal. Br J Nutr. 12:297, 1958.

56. Schroeder, L. J., Iacobellis, M. and Smith. A. H.: Influence of heat on the digestibility of meat protein. J Nutr. 73:143, 1961.

57. Jones, D. B. and Gerscoriff, C. E. F.: The effect of storage on the protein of wheat, white flour and whole flour. Cereal Chem. 18:417, 1941.

58. Jacquot and Adrian: Unpublished data 1982.

59. Hepburn, F. N., Lewis, E. W., Jr. and Elvenjem, C. A.: The amino acid content of wheat flour and bread. Cereal Chem. 34:312, 1957.

60. Anatharaman, K. and Carpenter, K. J.: Effects of heat treatment processing on the nutritional value of groundnut products. 1. Protein quality of groundnut cotyledons for rats. J Sci Food Agric. 20:703, 1969.

61. Tannous, R. I. and Ullah, M.: Effects of autoclaving on nutritional factors in legume seeds. Trop Agron Trin. 46:123, 1969.

62. Balasundaram, S., Cama, H. R., Malik, D. A. and Venkatesan, C: Nutritive value of differently processed groundnut meals and the effect of supplementation on the meals with amino acids antibiotics and vit B12. J Nutr. 66:75, 1958.

63. Hodge, J. E.: Origin of flavour in foods. Nonenzymatic browning reactions in Schultz, Day and Libbey. Chemistry and Physiology of flavours. Avi Westport. 1967.

64. Kenney, M. and Day, E. A.: Probable of the strecker degradation of amino acids in development of cheese flavour. J Dairy Sci. 40:874, 1957.

65. Patton, S.: Browning and associated changes in milk and its products: a review. J Dairy Sci. 38:457, 1964.

66. Collyer, D. M.: Bread flavour. Bakers Digest. 38:43, 1964.

67. Newell, J. A., Mason, M. E. and Matlock, R. S.: Precursors of typical and a-typical roasted peanut flavour. J Agric Food Chem. 14:767, 1967.

68. Wolform, M. L., Plunkett, R. A. and Cavalier, L. F.: Chemical reactions of amino compounds and sugars. 4. Significance of furan derivatives in colour formation. J Amer Chem Soc. 71:3518, 1949.

69. Agabalyants, G. G. and Platnow, I. B.: Nitrogen and sugar amines as an index in heat treatment of wine. Vinod Vinograd. 21:6, 1961.

70. Lingnert and Eriksson, C. E.: Antioxidative effect of Maillard reaction products. Prog Fd Nutr Soc. 5:453, 1981.

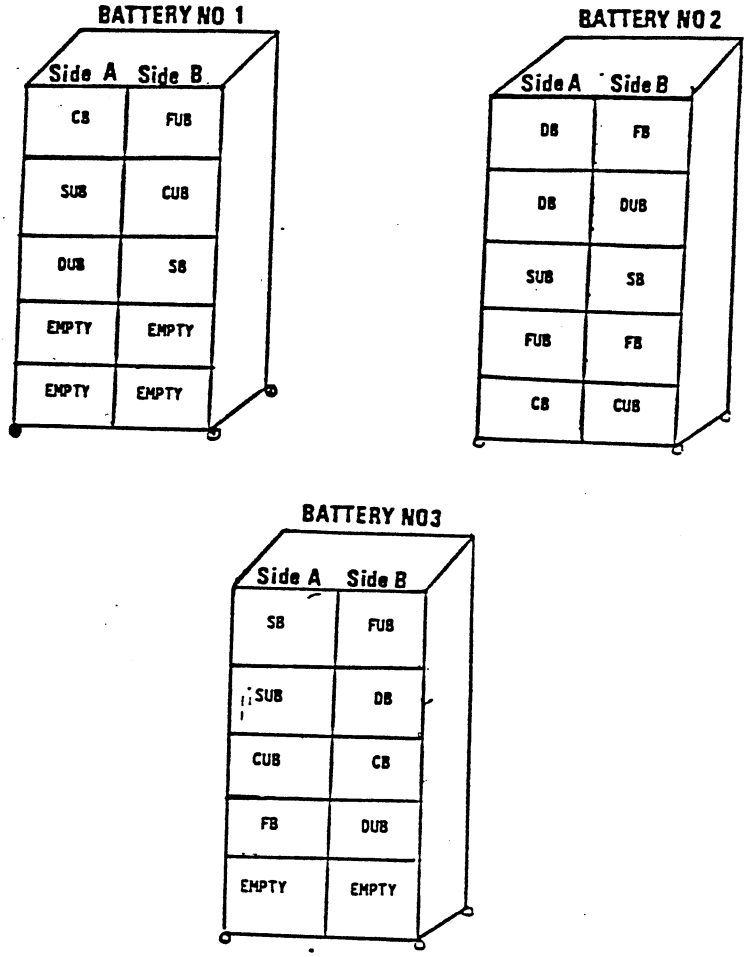
71. Fagerson, I. S.: Thermal degradation of carbohydrates: A review. J Agric Food Chem. 17:747, 1969.

# APPENDICES

# APPENDIX A

## SCHEMATIC REPRESENTATION OF CHICK BATTERY FEED INTAKE AND AVERAGE WEIGHT GAIN OF CHICKS IN EACH BATTERY

## Schematic Representation Of A Chick Battery




| | Battery No.1 (Gms) | Battery No.2 (Gms) | Battery No.3 (Gms) |
|---|---|---|---|
| No of Chicks | 34 | 58 | 45 |
| Total Feed Intake | 2887.84 | 3181.75 | 2667.00 |
| Feed Intake per Chick Side A | 87.48 | 57.85 | 59.48 |
| Total Feed Intake | 1640.00 | 1681.00 | 1497.00 |
| Feed Intake per Chick Side B | 96.47 | 67.24 | 71.29 |
| Total Feed Intake | 1247.00 | 1501.00 | 1180.00 |
| Feed Intake per Chick | 73.35 | 50.03 | 49.17 |
| Average weight gain | 44.96 | 83.93 | 58.12 |

# APPENDIX B

## VALUES OF DIFFERENT AMINO ACIDS IN EACH FEED

AS IS BASIS

NAME OF SAMPLE----------CUB
SAMPLE CHROMATOGRAM NUMBER----6
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.0854
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.85
PERCENT PROTEIN (N X 6.25)----17.8125

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 362.64 | .3626 | 63.696 | .1784 | .9312 | 5.5158 | LYS |
| HIS | 164.2 | .1642 | 28.841 | .1212 | .4475 | 2.6507 | HIS |
| NH3 | 1686.28 | 1.6863 | 296.185 | .4149 | .5044 | 2.9878 | NH3 |
| AGP | 500 | .5 | 87.822 | 0 | 0 | 0 | AGP |
| ARG | 319.64 | .3196 | 56.143 | .3146 | .978 | 5.7932 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 575.56 | .5756 | 101.094 | .1416 | 1.3456 | 7.9704 | ASP |
| THR | 323.72 | .3237 | 56.859 | .0796 | .6773 | 4.012 | THR |
| SER | 551.96 | .552 | 96.948 | .1358 | 1.0188 | 6.0351 | SER |
| GLU | 1295.12 | 1.2951 | 227.48 | .3186 | 3.3469 | 19.8255 | GLU |
| PRO | 515.96 | .516 | 90.625 | .1269 | 1.0434 | 6.1804 | PRO |
| GLY | 449.72 | .4497 | 78.991 | .1106 | .5931 | 3.513 | GLY |
| ALA | 512.68 | .5127 | 90.049 | .1261 | .8022 | 4.7521 | ALA |
| CYS/2 | 123.36 | .1234 | 21.667 | .0303 | .2603 | 1.5421 | CYS/2 |
| VAL | 441.92 | .4419 | 77.621 | .1087 | .9094 | 5.3869 | VAL |
| MET | 173.56 | .1736 | 30.485 | .0427 | .4549 | 2.6944 | MET |
| ILE | 333.6 | .3336 | 58.595 | .0821 | .7686 | 4.5531 | ILE |
| LEU | 571.4 | .5714 | 100.363 | .1406 | 1.3166 | 7.7987 | LEU |
| NLE | 500 | .5 | 87.822 | 0 | 0 | 0 | NLE |
| TYR | 200 | .2 | 35.129 | .0492 | .6365 | 3.7703 | TYR |
| PHE | 292 | .292 | 51.288 | .0718 | .8472 | 5.0186 | PHE |
| ***TOTALS*** | | | | 2.5939 | 16.8819 | 100 | |

RECOVERED NITROGEN= 91.0141439%

NAME OF SAMPLE----------CUB
SAMPLE CHROMATOGRAM NUMBER----6
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.0789688399
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.08241402
PERCENT PROTEIN (N X 6.25)----19.2650876

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 362.64 | .3626 | 68.89 | .193 | 1.0071 | 5.5158 | LYS |
| HIS | 164.2 | .1642 | 31.193 | .1311 | .484 | 2.6507 | HIS |
| NH3 | 1686.28 | 1.6863 | 320.339 | .4487 | .5455 | 2.9878 | NH3 |
| AGP | 500 | .5 | 94.984 | 0 | 0 | 0 | AGP |
| ARG | 319.64 | .3196 | 60.721 | .3402 | 1.0578 | 5.7932 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 575.56 | .5756 | 109.338 | .1531 | 1.4553 | 7.9704 | ASP |
| THR | 323.72 | .3237 | 61.496 | .0861 | .7325 | 4.012 | THR |
| SER | 551.96 | .552 | 104.855 | .1469 | 1.1019 | 6.0351 | SER |
| GLU | 1295.12 | 1.2951 | 246.031 | .3446 | 3.6199 | 19.8255 | GLU |
| PRO | 515.96 | .516 | 98.016 | .1373 | 1.1285 | 6.1804 | PRO |
| GLY | 449.72 | .4497 | 85.432 | .1197 | .6414 | 3.513 | GLY |
| ALA | 512.68 | .5127 | 97.393 | .1364 | .8677 | 4.7521 | ALA |
| CYS/2 | 123.36 | .1234 | 23.434 | .0328 | .2816 | 1.5421 | CYS/2 |
| VAL | 441.92 | .4419 | 83.95 | .1176 | .9836 | 5.3869 | VAL |
| MET | 173.56 | .1736 | 32.971 | .0462 | .492 | 2.6944 | MET |
| ILE | 333.6 | .3336 | 63.373 | .0888 | .8313 | 4.5531 | ILE |
| LEU | 571.4 | .5714 | 108.547 | .152 | 1.4239 | 7.7987 | LEU |
| NLE | 500 | .5 | 94.984 | 0 | 0 | 0 | NLE |
| TYR | 200 | .2 | 37.994 | .0532 | .6884 | 3.7703 | TYR |
| PHE | 292 | .292 | 55.471 | .0777 | .9163 | 5.0186 | PHE |
| ***TOTALS*** | | | | 2.8054 | 18.2586 | 100 | |

RECOVERED NITROGEN= 91.0141439%

AS IS BASIS

NAME OF SAMPLE----------DUB
SAMPLE CHROMATOGRAM NUMBER----97
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.0833
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.94
PERCENT PROTEIN (N X 6.25)----18.375

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 344.88 | .3449 | 62.103 | .174 | .9079 | 5.5487 | LYS |
| HIS | 149.28 | .1493 | 26.881 | .113 | .4171 | 2.5491 | HIS |
| NH3 | 1475 | 1.475 | 265.606 | .372 | .4523 | 2.7645 | NH3 |
| AGP | 500 | .5 | 90.036 | 0 | 0 | 0 | AGP |
| ARG | 294.96 | .295 | 53.114 | .2976 | .9252 | 5.6548 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 551.36 | .5514 | 99.285 | .1391 | 1.3215 | 8.0765 | ASP |
| THR | 306.56 | .3066 | 55.203 | .0773 | .6576 | 4.0189 | THR |
| SER | 535.36 | .5354 | 96.403 | .135 | 1.0131 | 6.1918 | SER |
| GLU | 1210.88 | 1.2101 | 217.902 | .3052 | 3.206 | 19.5941 | GLU |
| PRO | 468.56 | .4686 | 84.375 | .1182 | .9714 | 5.9369 | PRO |
| GLY | 425.76 | .4258 | 76.667 | .1074 | .5756 | 3.518 | GLY |
| ALA | 491.32 | .4913 | 88.473 | .1239 | .7882 | 4.8173 | ALA |
| CYS/2 | 127.8 | .1278 | 23.013 | .0322 | .2765 | 1.6899 | CYS/2 |
| VAL | 426.36 | .4264 | 76.776 | .1075 | .8995 | 5.4975 | VAL |
| MET | 174.72 | .1747 | 31.462 | .0441 | .4694 | 2.8691 | MET |
| ILE | 314.8 | .3148 | 56.687 | .0794 | .7436 | 4.5448 | ILE |
| LEU | 541.6 | .5416 | 97.527 | .0366 | 1.2794 | 7.8191 | LEU |
| NLE | 500 | .5 | 90.036 | 0 | 0 | 0 | NLE |
| TYR | 193.68 | .1937 | 34.876 | .0489 | .6319 | 3.8621 | TYR |
| PHE | 277.6 | .2776 | 49.988 | .07 | .8258 | 5.0468 | PHE |
| ***TOTALS*** | | | | 2.4814 | 16.362 | 100 | |

RECOVERED NITROGEN= 84.4015397%

DRY MATTER BASIS

NAME OF SAMPLE----------DUB
SAMPLE CHROMATOGRAM NUMBER----97
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.07687757
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.18561058
PERCENT PROTEIN (N X 6.25)----19.9100661

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 344.88 | .3449 | 67.291 | .1885 | .9837 | 5.5487 | LYS |
| HIS | 149.28 | .1493 | 29.127 | .1224 | .4519 | 2.5491 | HIS |
| NH3 | 1475 | 1.475 | 287.795 | .4031 | .4901 | 2.7645 | NH3 |
| AGP | 500 | .5 | 97.558 | 0 | 0 | 0 | AGP |
| ARG | 294.96 | .295 | 57.551 | .3224 | 1.0025 | 5.6548 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 551.36 | .5514 | 107.579 | .1507 | 1.4319 | 8.0765 | ASP |
| THR | 306.56 | .3066 | 59.815 | .0838 | .7125 | 4.0189 | THR |
| SER | 535.36 | .5354 | 104.457 | .1463 | 1.0977 | 6.1918 | SER |
| GLU | 1210.08 | 1.2101 | 236.105 | .3307 | 3.4738 | 19.5941 | GLU |
| PRO | 468.56 | .4686 | 91.423 | .1281 | 1.0526 | 5.9369 | PRO |
| GLY | 425.76 | .4258 | 83.072 | .1164 | .6237 | 3.518 | GLY |
| ALA | 491.32 | .4913 | 95.864 | .1343 | .8541 | 4.8173 | ALA |
| CYS/2 | 127.8 | .1278 | 24.936 | .0349 | .2996 | 1.6899 | CYS/2 |
| VAL | 426.36 | .4264 | 83.189 | .1165 | .9746 | 5.4975 | VAL |
| MET | 174.72 | .1747 | 34.091 | .0478 | .5087 | 2.8691 | MET |
| ILE | 314.8 | .3148 | 61.422 | .086 | .8057 | 4.5448 | ILE |
| LEU | 541.6 | .5416 | 105.675 | .148 | 1.3862 | 7.8191 | LEU |
| NLE | 500 | .5 | 97.558 | 0 | 0 | 0 | NLE |
| TYR | 193.68 | .1937 | 37.79 | .0529 | .6847 | 3.8621 | TYR |
| PHE | 277.6 | .2776 | 54.164 | .0759 | .8947 | 5.0468 | PHE |
| ***TOTALS*** | | | | 2.6887 | 17.7289 | 100 | |

RECOVERED NITROGEN= 84.4015397%

DRY MATTER BASIS

NAME OF SAMPLE----------FUB
SAMPLE CHROMATOGRAM NUMBER----4
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.079166
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.08695652
PERCENT PROTEIN (N X 6.25)----19.2934783

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GM/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 364.68 | .3647 | 69.098 | .1936 | 1.8101 | 5.567 | LYS |
| HIS | 161.2 | .1612 | 30.543 | .1283 | .4739 | 2.6118 | HIS |
| NH3 | 1713.2 | 1.7132 | 324.609 | .4547 | .5528 | 3.0466 | NH3 |
| AGP | 500 | .5 | 94.738 | 0 | 0 | 0 | AGP |
| ARG | 314.84 | .3148 | 59.654 | .3342 | 1.0392 | 5.727 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 560.68 | .5607 | 106.235 | .1488 | 1.414 | 7.7927 | ASP |
| THR | 312.56 | .3126 | 59.222 | .083 | .7055 | 3.8879 | THR |
| SER | 564.68 | .5647 | 106.993 | .1499 | 1.1244 | 6.1966 | SER |
| GLU | 1313.6 | 1.3136 | 248.895 | .3486 | 3.662 | 20.1816 | GLU |
| PRO | 509.28 | .5093 | 96.496 | .1352 | 1.111 | 6.1226 | PRO |
| GLY | 457.52 | .4575 | 86.689 | .1214 | .6509 | 3.587 | GLY |
| ALA | 524.12 | .5241 | 99.308 | .1391 | .8847 | 4.8759 | ALA |
| CYS/2 | 110.23 | .1102 | 20.886 | .0293 | .2509 | 1.383 | CYS/2 |
| VAL | 432.48 | .4325 | 81.944 | .1148 | .9601 | 5.291 | VAL |
| MET | 166.96 | .167 | 31.635 | .0443 | .472 | 2.6014 | MET |
| ILE | 328.2 | .3282 | 62.186 | .0871 | .8158 | 4.4957 | ILE |
| LEU | 570.48 | .5705 | 108.092 | .1514 | 1.4179 | 7.8145 | LEU |
| NLE | 500 | .5 | 94.738 | 0 | 0 | 0 | NLE |
| TYR | 200.2 | .2002 | 37.933 | .0531 | .6873 | 3.7878 | TYR |
| PHE | 291.6 | .2916 | 55.251 | .0774 | .9127 | 5.0299 | PHE |
| ***TOTALS*** | | | | 2.7941 | 18.1451 | 100 | |

AS IS BASIS

NAME OF SAMPLE----------FUB
SAMPLE CHROMATOGRAM NUMBER----4
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.08605
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.84
PERCENT PROTEIN (N X 6.25)----17.75

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 364.68 | .3647 | 63.57 | .1781 | .9293 | 5.567 | LYS |
| HIS | 161.2 | .1612 | 28.1 | .1181 | .436 | 2.6118 | HIS |
| NH3 | 1713.2 | 1.7132 | 298.64 | .4183 | .5086 | 3.0466 | NH3 |
| AGP | 500 | .5 | 87.159 | 0 | 0 | 0 | AGP |
| ARG | 314.84 | .3148 | 54.882 | .3075 | .956 | 5.727 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 560.68 | .5607 | 97.736 | .1369 | 1.3009 | 7.7927 | ASP |
| THR | 312.56 | .3126 | 54.485 | .0763 | .649 | 3.8879 | THR |
| SER | 564.68 | .5647 | 98.433 | .1379 | 1.0344 | 6.1966 | SER |
| GLU | 1313.6 | 1.3136 | 228.983 | .3207 | 3.369 | 20.1816 | GLU |
| PRO | 509.28 | .5093 | 88.776 | .1243 | 1.0221 | 6.1226 | PRO |
| GLY | 457.52 | .4575 | 79.754 | .1117 | .5988 | 3.587 | GLY |
| ALA | 524.12 | .5241 | 91.363 | .128 | .814 | 4.8759 | ALA |
| CYS/2 | 110.23 | .1102 | 19.215 | .0269 | .2309 | 1.383 | CYS/2 |
| VAL | 432.48 | .4325 | 75.389 | .1056 | .8833 | 5.291 | VAL |
| MET | 166.96 | .167 | 29.104 | .0408 | .4343 | 2.6014 | MET |
| ILE | 328.2 | .3282 | 57.211 | .0801 | .7505 | 4.4957 | ILE |
| LEU | 570.48 | .5705 | 99.445 | .1393 | 1.3045 | 7.8145 | LEU |
| NLE | 500 | .5 | 87.159 | 0 | 0 | 0 | NLE |
| TYR | 200.2 | .2002 | 34.898 | .0489 | .6323 | 3.7878 | TYR |
| PHE | 291.6 | .2916 | 50.831 | .0712 | .8397 | 5.0299 | PHE |
| ***TOTALS*** | | | | 2.5706 | 16.6935 | 100 | |

AS IS BASIS

NAME OF SAMPLE----------SUB
SAMPLE CHROMATOGRAM NUMBER----96
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.0845
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------2.89
PERCENT PROTEIN (N X 6.25)----18.0625

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 368.28 | .3683 | 65.375 | .1831 | .9557 | 5.571 | LYS |
| HIS | 158.04 | .158 | 28.054 | .1179 | .4353 | 2.5374 | HIS |
| NH3 | 1595.16 | 1.5952 | 283.164 | .3966 | .4822 | 2.811 | NH3 |
| AGP | 500 | .5 | 88.757 | 0 | 0 | 0 | AGP |
| ARG | 310.48 | .3105 | 55.115 | .3088 | .9601 | 5.5965 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 576.8 | .5768 | 102.391 | .1434 | 1.3628 | 7.944 | ASP |
| THR | 323.52 | .3235 | 57.43 | .0804 | .6841 | 3.9877 | THR |
| SER | 564.12 | .5641 | 100.14 | .1403 | 1.0524 | 6.1343 | SER |
| GLU | 1308.04 | 1.308 | 232.196 | .3252 | 3.4163 | 19.9139 | GLU |
| PRO | 493.56 | .4936 | 87.614 | .1227 | 1.0087 | 5.8798 | PRO |
| GLY | 452.56 | .4526 | 80.336 | .1125 | .6032 | 3.5159 | GLY |
| ALA | 523.8 | .5238 | 92.982 | .1302 | .8284 | 4.8287 | ALA |
| CYS/2 | 126.56 | .1266 | 22.466 | .0315 | .2699 | 1.5735 | CYS/2 |
| VAL | 455.8 | .4558 | 80.911 | .1133 | .948 | 5.5257 | VAL |
| MET | 190.44 | .1904 | 33.806 | .0474 | .5044 | 2.9403 | MET |
| ILE | 337.4 | .3374 | 59.893 | .0839 | .7857 | 4.5798 | ILE |
| LEU | 576.96 | .577 | 102.419 | .1435 | 1.3435 | 7.8316 | LEU |
| NLE | 500 | .5 | 88.757 | 0 | 0 | 0 | NLE |
| TYR | 201.64 | .2016 | 35.794 | .0501 | .6486 | 3.7805 | TYR |
| PHE | 295.36 | .2954 | 52.431 | .0734 | .8661 | 5.0486 | PHE |
| ***TOTALS*** | | | | 2.6044 | 17.1554 | 100 | |

RECOVERED NITROGEN= 90.1170914%

DRY MATTER BASIS

NAME OF SAMPLE----------SUB
SAMPLE CHROMATOGRAM NUMBER----96
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.07928635
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.08003837
PERCENT PROTEIN (N X 6.25)----19.2502398

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | G%A/ 100G | G%A/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 368.28 | .3683 | 69.674 | .1952 | 1.0186 | 5.571 | LYS |
| HIS | 158.04 | .158 | 29.899 | .1256 | .4639 | 2.5374 | HIS |
| NH3 | 1595.16 | 1.5952 | 301.785 | .4227 | .5139 | 2.811 | NH3 |
| AGP | 500 | .5 | 94.594 | 0 | 0 | 0 | AGP |
| ARG | 310.48 | .3105 | 58.739 | .3291 | 1.0232 | 5.5965 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 576.8 | .5768 | 109.123 | .1528 | 1.4524 | 7.944 | ASP |
| THR | 323.52 | .3235 | 61.206 | .0857 | .7291 | 3.9877 | THR |
| SER | 564.12 | .5641 | 106.725 | .1495 | 1.1216 | 6.1343 | SER |
| GLU | 1388.04 | 1.388 | 247.465 | .3466 | 3.641 | 19.9139 | GLU |
| PRO | 493.56 | .4936 | 93.375 | .1308 | 1.075 | 5.8798 | PRO |
| GLY | 452.56 | .4526 | 85.619 | .1199 | .6428 | 3.5159 | GLY |
| ALA | 523.8 | .5238 | 99.097 | .1388 | .8829 | 4.8287 | ALA |
| CYS/2 | 126.56 | .1266 | 23.944 | .0335 | .2877 | 1.5735 | CYS/2 |
| VAL | 455.8 | .4558 | 86.232 | .1208 | 1.0103 | 5.5257 | VAL |
| MET | 190.44 | .1904 | 36.029 | .0505 | .5376 | 2.9403 | MET |
| ILE | 337.4 | .3374 | 63.832 | .0894 | .8373 | 4.5798 | ILE |
| LEU | 576.96 | .577 | 109.154 | .1529 | 1.4319 | 7.8316 | LEU |
| NLE | 500 | .5 | 94.594 | 0 | 0 | 0 | NLE |
| TYR | 201.64 | .2016 | 38.148 | .0534 | .6912 | 3.7805 | TYR |
| PHE | 295.36 | .2954 | 55.878 | .0783 | .9231 | 5.0486 | PHE |
| ***TOTALS*** | | | | 2.7756 | 18.2834 | 100 | |

RECOVERED NITROGEN= 90.1170914%

DRY MATTER BASIS

NAME OF SAMPLE----------CB
SAMPLE CHROMATOGRAM NUMBER----98
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.0767016
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.17164179
PERCENT PROTEIN (N X 6.25)----19.8227612

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GM/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 310.08 | .3101 | 60.64 | .1699 | .8865 | 5.035 | LYS |
| HIS | 145.64 | .1456 | 28.482 | .1197 | .4419 | 2.5099 | HIS |
| NH3 | 1493.32 | 1.4933 | 292.038 | .4091 | .4973 | 2.8247 | NH3 |
| AGP | 500 | .5 | 97.782 | 0 | 0 | 0 | AGP |
| ARG | 281.48 | .2815 | 55.047 | .3084 | .9589 | 5.4463 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 530.64 | .5306 | 103.774 | .1454 | 1.3812 | 7.8448 | ASP |
| THR | 297.56 | .2976 | 58.192 | .0815 | .6932 | 3.937 | THR |
| SER | 534 | .534 | 104.431 | .1463 | 1.0975 | 6.2331 | SER |
| GLU | 1231.56 | 1.2316 | 240.848 | .3374 | 3.5436 | 20.1261 | GLU |
| PRO | 477.72 | .4777 | 93.424 | .1309 | 1.0756 | 6.1089 | PRO |
| GLY | 427.92 | .4279 | 83.685 | .1172 | .6283 | 3.5685 | GLY |
| ALA | 488.16 | .4882 | 95.466 | .1337 | .8505 | 4.8305 | ALA |
| CYS/2 | 124.28 | .1243 | 24.305 | .034 | .292 | 1.6586 | CYS/2 |
| VAL | 431.12 | .4311 | 84.311 | .1181 | .9878 | 5.6102 | VAL |
| MET | 175.48 | .1755 | 34.317 | .0481 | .5121 | 2.9082 | MET |
| ILE | 315.8 | .3158 | 61.759 | .0865 | .8107 | 4.6013 | ILE |
| LEU | 541.12 | .5411 | 105.823 | .1482 | 1.388 | 7.8843 | LEU |
| NLE | 500 | .5 | 97.782 | 0 | 0 | 0 | NLE |
| TYR | 190.4 | .1904 | 37.235 | .0522 | .6747 | 3.8318 | TYR |
| PHE | 274.72 | .2747 | 53.725 | .0753 | .8875 | 5.0405 | PHE |
| ***TOTALS*** | | | | 2.6617 | 17.6069 | 100 | |

RECOVERED NITROGEN= 83.9209859%

AS IS BASIS

NAME OF SAMPLE----------CB
SAMPLE CHROMATOGRAM NUMBER----98
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.0795
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.06
PERCENT PROTEIN (N X 6.25)----19.125

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 310.08 | .3101 | 58.506 | .1639 | .8553 | 5.035 | LYS |
| HIS | 145.64 | .1456 | 27.479 | .1155 | .4264 | 2.5099 | HIS |
| NH3 | 1493.32 | 1.4933 | 281.758 | .3947 | .4798 | 2.8247 | NH3 |
| AGP | 500 | .5 | 94.34 | 0 | 0 | 0 | AGP |
| ARG | 281.48 | .2815 | 53.109 | .2976 | .9252 | 5.4463 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 530.64 | .5306 | 100.121 | .1402 | 1.3326 | 7.8448 | ASP |
| THR | 297.56 | .2976 | 56.143 | .0786 | .6688 | 3.937 | THR |
| SER | 534 | .534 | 100.755 | .1411 | 1.0588 | 6.2331 | SER |
| GLU | 1231.56 | 1.2316 | 232.37 | .3255 | 3.4189 | 20.1261 | GLU |
| PRO | 477.72 | .4777 | 90.136 | .1263 | 1.0377 | 6.1089 | PRO |
| GLY | 427.92 | .4279 | 80.74 | .1131 | .6062 | 3.5685 | GLY |
| ALA | 488.16 | .4882 | 92.106 | .129 | .8206 | 4.8305 | ALA |
| CYS/2 | 124.28 | .1243 | 23.449 | .0328 | .2817 | 1.6586 | CYS/2 |
| VAL | 431.12 | .4311 | 81.343 | .1139 | .953 | 5.6102 | VAL |
| MET | 175.48 | .1755 | 33.109 | .0464 | .494 | 2.9082 | MET |
| ILE | 315.8 | .3158 | 59.585 | .083 | .7816 | 4.6013 | ILE |
| LEU | 541.12 | .5411 | 102.098 | .143 | 1.3393 | 7.8843 | LEU |
| NLE | 5^9 | .5 | 94.34 | 0 | 0 | 0 | NLE |
| TYR | 1. .4 | .1904 | 35.925 | .050 | .6589 | 3.8318 | TYR |
| PHE | 27 .72 | .2747 | 51.834 | .0726 | .8562 | 5.0405 | PHE |
| ***TOTALS*** | | | | 2.568 | 16.9871 | 100 | |

RECOVERED NITROGEN= 83.9209859%

AS IS BASIS

NAME OF SAMPLE----------FB
SAMPLE CHROMATOGRAM NUMBER----99
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.0814
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.01
PERCENT PROTEIN [illegible]

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 258.76 | .2588 | 47.683 | .1336 | .6971 | 4.2785 | LYS |
| HIS | 145.68 | .1457 | 26.845 | .1128 | .4165 | 2.5565 | HIS |
| NH3 | 1440.8 | 1.4408 | 265.504 | .3719 | .4522 | 2.7752 | NH3 |
| AGP | 500 | .5 | 92.138 | 0 | 0 | 0 | AGP |
| ARG | 266.04 | .266 | 49.025 | .2747 | .854 | 5.2417 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 557 | .557 | 102.641 | .1438 | 1.3662 | 8.3851 | ASP |
| THR | 306.96 | .307 | 56.565 | .0792 | .6738 | 4.1356 | THR |
| SER | 528.44 | .5284 | 97.378 | .1364 | 1.0233 | 6.281 | SER |
| GLU | 1208.24 | 1.2082 | 222.649 | .3119 | 3.2758 | 20.1061 | GLU |
| PRO | 469.44 | .4694 | 86.506 | .1212 | .9959 | 6.1128 | PRO |
| GLY | 419.6 | .4196 | 77.322 | .1083 | .5805 | 3.5631 | GLY |
| ALA | 480.2 | .4802 | 88.489 | .1239 | .7883 | 4.8386 | ALA |
| CYS/2 | 117.16 | .1172 | 21.59 | .0302 | .2594 | 1.5921 | CYS/2 |
| VAL | 423.04 | .423 | 77.956 | .1092 | .9133 | 5.6058 | VAL |
| MET | 176.64 | .1766 | 32.55 | .0456 | .4857 | 2.981 | MET |
| ILE | 313.32 | .3133 | 57.737 | .0809 | .7574 | 4.6487 | ILE |
| LEU | 537.08 | .5371 | 98.971 | .1386 | 1.2983 | 7.9686 | LEU |
| NLE | 500 | .5 | 92.138 | 0 | 0 | 0 | NLE |
| TYR | 186.12 | .1861 | 34.297 | .048 | .6214 | 3.8142 | TYR |
| PHE | 273.8 | .2738 | 50.455 | .0707 | .8335 | 5.1155 | PHE |
| ***TOTALS*** | | | | 2.4409 | 16.2927 | 100 | |

RECOVERED NITROGEN= 81.0920238%

DRY MATTER BASIS

NAME OF SAMPLE----------FB
SAMPLE CHROMATOGRAM NUMBER----99
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.07760676
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.15712188
PERCENT PROTEIN (N X 6.25)----19.7320117

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 258.76 | .2588 | 50.014 | .1401 | .7312 | 4.2785 | LYS |
| HIS | 145.68 | .1457 | 28.157 | .1183 | .4369 | 2.5565 | HIS |
| NH3 | 1440.8 | 1.4408 | 278.481 | .3901 | .4743 | 2.7752 | NH3 |
| AGP | 500 | .5 | 96.641 | 0 | 0 | 0 | AGP |
| ARG | 266.04 | .266 | 51.421 | .2881 | .8957 | 5.2417 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 557 | .557 | 107.658 | .1508 | 1.4329 | 8.3851 | ASP |
| THR | 306.96 | .307 | 59.33 | .0831 | .7067 | 4.1356 | THR |
| SER | 528.44 | .5284 | 102.138 | .1431 | 1.0734 | 6.281 | SER |
| GLU | 1208.24 | 1.2082 | 233.531 | .3271 | 3.4359 | 20.1061 | GLU |
| PRO | 469.44 | .4694 | 90.734 | .1271 | 1.0446 | 6.1128 | PRO |
| GLY | 419.6 | .4196 | 81.101 | .1136 | .6089 | 3.5631 | GLY |
| ALA | 480.2 | .4802 | 92.814 | .13 | .8269 | 4.8386 | ALA |
| CYS/2 | 117.16 | .1172 | 22.645 | .0317 | .2721 | 1.5921 | CYS/ |
| VAL | 423.04 | .423 | 81.766 | .1145 | .958 | 5.6058 | VAL |
| MET | 176.64 | .1766 | 34.141 | .0478 | .5094 | 2.981 | MET |
| ILE | 313.32 | .3133 | 60.5[illegible] | .0848 | .7944 | 4.6487 | ILE |
| LEU | 537.08 | .5371 | 103.[illegible]8 | .1454 | 1.3618 | 7.9686 | LEU |
| NLE | 500 | .5 | 96.64 | 0 | 0 | 0 | NLE |
| TYR | 186.12 | .1[illegible]31 | 35.9[illegible] | .0504 | .6518 | 3.8142 | TYR |
| PHE | 273.8 | .2[illegible]38 | 52.921 | .0741 | .8742 | 5.1155 | PHE |
| ***TOTALS*** | | | | 2.5602 | 17.0891 | 100 | |

RECOVERED NITROGEN= 81.0920238%

DRY MATTER BASIS

NAME OF SAMPLE----------DB
SAMPLE CHROMATOGRAM NUMBER----3
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.07620494
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.18663068
PERCENT PROTEIN (N X 6.25)----19.9164418

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 281.8 | .2818 | 55.469 | .1554 | .8109 | 4.386 | LYS |
| HIS | 153.24 | .1532 | 30.163 | .1267 | .468 | 2.5314 | HIS |
| NH3 | 2052.84 | 2.052 | 403.919 | .5658 | .6879 | 3.7206 | NH3 |
| AGP | 500 | .5 | 98.419 | 0 | 0 | 0 | AGP |
| ARG | 263.96 | .264 | 51.957 | .2911 | .9051 | 4.8955 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 563.68 | .5637 | 110.953 | .1554 | 1.4768 | 7.9877 | ASP |
| THR | 384.6 | .3846 | 59.957 | .084 | .7142 | 3.863 | THR |
| SER | 542.52 | .5425 | 106.788 | .1496 | 1.1222 | 6.07 | SER |
| GLU | 1305.64 | 1.3056 | 256.999 | .36 | 3.7812 | 20.4521 | GLU |
| PRO | 508.88 | .5089 | 100.167 | .1403 | 1.1532 | 6.2376 | PRO |
| GLY | 453.32 | .4533 | 89.23 | .125 | .6699 | 3.6236 | GLY |
| ALA | 515.6 | .5156 | 101.489 | .1422 | .9042 | 4.8905 | ALA |
| CYS/2 | 104.64 | .1046 | 20.597 | .0289 | .2475 | 1.3385 | CYS/2 |
| VAL | 437.84 | .4378 | 86.183 | .1207 | 1.0097 | 5.4614 | VAL |
| MET | 182.6 | .1826 | 35.943 | .0503 | .5363 | 2.9008 | MET |
| ILE | 335.52 | .3355 | 66.043 | .0925 | .8664 | 4.686 | ILE |
| LEU | 575.68 | .5757 | 113.315 | .1587 | 1.4865 | 8.0401 | LEU |
| NLE | 500 | .5 | 98.419 | 0 | 0 | 0 | NLE |
| TYR | 194.8 | .1948 | 38.344 | .0537 | .6948 | 3.7578 | TYR |
| PHE | 293.24 | .2932 | 57.721 | .0808 | .9535 | 5.1573 | PHE |
| ***TOTALS*** | | | | 2.8811 | 18.4882 | 100 | |

RECOVERED NITROGEN= 90.4122584%

DRY MATTER BASIS

NAME OF SAMPLE----------DB
SAMPLE CHROMATOGRAM NUMBER----3
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.07620494
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.18663068
PERCENT PROTEIN (N X 6.25)----19.9164418

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 281.8 | .2818 | 55.469 | .1554 | .8109 | 4.386 | LYS |
| HIS | 153.24 | .1532 | 30.163 | .1267 | .468 | 2.5314 | HIS |
| NH3 | 2052.84 | 2.052 | 403.919 | .5658 | .6879 | 3.7206 | NH3 |
| AGP | 500 | .5 | 98.419 | 0 | 0 | 0 | AGP |
| ARG | 263.96 | .264 | 51.957 | .2911 | .9051 | 4.8955 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 563.68 | .5637 | 110.953 | .1554 | 1.4768 | 7.9877 | ASP |
| THR | 304.6 | .3046 | 59.957 | .084 | .7142 | 3.863 | THR |
| SER | 542.52 | .5425 | 106.788 | .1496 | 1.1222 | 6.07 | SER |
| GLU | 1305.64 | 1.3056 | 256.999 | .36 | 3.7812 | 20.4521 | GLU |
| PRO | 508.88 | .5089 | 100.167 | .1403 | 1.1532 | 6.2376 | PRO |
| GLY | 453.32 | .4533 | 89.23 | .125 | .6699 | 3.6236 | GLY |
| ALA | 515.6 | .5156 | 101.489 | .1422 | .9042 | 4.8905 | ALA |
| CYS/2 | 104.64 | .1046 | 20.597 | .0289 | .2475 | 1.3385 | CYS/2 |
| VAL | 437.84 | .4378 | 86.183 | .1207 | 1.0097 | 5.4614 | VAL |
| MET | 182.6 | .1826 | 35.943 | .0503 | .5363 | 2.9008 | MET |
| ILE | 335.52 | .3355 | 66.043 | .0925 | .8664 | 4.686 | IL |
| LEU | 575.68 | .5757 | 113.315 | .1587 | 1.4865 | 8.0401 | LE |
| NLE | 500 | .5 | 98.419 | 0 | 0 | 0 | NL |
| TYR | 194.8 | .1948 | 38.344 | .0537 | .6948 | 3.7578 | TY |
| PHE | 293.24 | .2932 | 57.721 | .0808 | .9535 | 5.1573 | PHE |
| ***TOTALS*** | | | | 2.8811 | 18.4882 | 100 | |

RECOVERED NITROGEN= 90.4122584%

DRY MATTER BASIS

NAME OF SAMPLE----------SB
-SAMPLE CHROMATOGRAM NUMBER----100
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.07918569
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.10635672
PERCENT PROTEIN (N X 6.25)----19.4147295

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 334.52 | .3345 | 63.368 | .1775 | .9264 | 5.4226 | LYS |
| HIS | 144.92 | .1449 | 27.452 | .1154 | .4259 | 2.4933 | HIS |
| NH3 | 1491.12 | 1.4911 | 282.46 | .3956 | .481 | 2.8157 | NH3 |
| AGP | 500 | .5 | 94.714 | 0 | 0 | 0 | AGP |
| ARG | 286.2 | .2862 | 54.214 | .3038 | .9444 | 5.5282 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 548.64 | .5486 | 103.928 | .1456 | 1.3833 | 8.0971 | ASP |
| THR | 305.32 | .3053 | 57.836 | .081 | .6889 | 4.0328 | THR |
| SER | 548.08 | .5481 | 103.822 | .1454 | 1.0911 | 6.3866 | SER |
| GLU | 1218.08 | 1.2181 | 230.739 | .3232 | 3.3949 | 19.872 | GLU |
| PRO | 483.16 | .4832 | 91.524 | .1282 | 1.0537 | 6.168 | PRO |
| GLY | 420.12 | .4201 | 79.583 | .1115 | .5975 | 3.4975 | GLY |
| ALA | 480.2 | .4802 | 90.963 | .1274 | .8104 | 4.7437 | ALA |
| CYS/2 | 120.72 | .1207 | 22.868 | .032 | .2748 | 1.6083 | CYS/2 |
| VAL | 416.6 | .4166 | 78.916 | .1105 | .9246 | 5.4121 | VAL |
| MET | 174.84 | .1748 | 33.12 | .0464 | .4942 | 2.8927 | MET |
| ILE | 310.4 | .3104 | 58.799 | .0824 | .7713 | 4.515 | ILE |
| LEU | 537.28 | .5373 | 101.776 | .1426 | 1.3351 | 7.8151 | LEU |
| NLE | 500 | .5 | 94.714 | 0 | 0 | 0 | NLE |
| TYR | 188.04 | .188 | 35.62 | .0499 | .6454 | 3.7779 | TYR |
| PHE | 268.68 | .2687 | 50.896 | .0713 | .8407 | 4.9214 | PHE |
| ***TOTALS*** | | | | 2.5896 | 17.0836 | 100 | |

RECOVERED NITROGEN= 83.3647252%

AS IS BASIS

NAME OF SAMPLE----------SB
SAMPLE CHROMATOGRAM NUMBER----100
SAMPLE ANALYSIS DATE----------8-84
WEIGHT OF SAMPLE (IN GRAMS)---.08145
SAMPLE DILUTION (IN MLS)------15
PERCENT NITROGEN----------3.02
PERCENT PROTEIN (N X 6.25)----18.875

| AMINO ACID | NMOL/ ML | UMOL/ ML | UMOL/ G | GN/ 100G | GAA/ 100G | GAA/ 100G(CP) | AMINO ACID |
|---|---|---|---|---|---|---|---|
| LYS | 334.92 | .3345 | 61.606 | .1726 | .9000 | 5.4226 | LYS |
| HIS | 144.92 | .1449 | 26.689 | .1121 | .4141 | 2.4933 | HIS |
| NH3 | 1491.12 | 1.4911 | 274.608 | .3846 | .4677 | 2.8157 | NH3 |
| AGP | 500 | .5 | 92.081 | 0 | 0 | 0 | AGP |
| ARG | 286.2 | .2862 | 52.707 | .2953 | .9182 | 5.5282 | ARG |
| CYS | 0 | 0 | 0 | 0 | 0 | 0 | CYS |
| ASP | 548.64 | .5486 | 101.039 | .1415 | 1.3448 | 8.0971 | ASP |
| THR | 305.32 | .3053 | 56.228 | .0788 | .6698 | 4.0328 | THR |
| SER | 548.08 | .5481 | 100.936 | .1414 | 1.0607 | 6.3866 | SER |
| GLU | 1218.08 | 1.2181 | 224.324 | .3142 | 3.3005 | 19.872 | GLU |
| PRO | 483.16 | .4832 | 88.98 | .1246 | 1.0244 | 6.168 | PRO |
| GLY | 420.12 | .4201 | 77.37 | .1084 | .5809 | 3.4975 | GLY |
| ALA | 480.2 | .4802 | 88.435 | .1239 | .7879 | 4.7437 | ALA |
| CYS/2 | 120.72 | .1207 | 22.232 | .0311 | .2671 | 1.6083 | CYS/2 |
| VAL | 416.6 | .4166 | 76.722 | .1075 | .8989 | 5.4121 | VAL |
| MET | 174.84 | .1748 | 32.199 | .0451 | .4804 | 2.8927 | MET |
| ILE | 310.4 | .3132 | 57.183 | .0801 | .7499 | 4.515 | ILE |
| LEU | 537.28 | .5373 | 98.947 | .1386 | 1.298 | 7.8151 | LEU |
| NLE | 500 | .5 | 92.081 | 0 | 0 | 0 | NLE |
| TYR | 188.04 | .188 | 34.63 | .0485 | .6275 | 3.7779 | TYR |
| PHE | 268.68 | .2687 | 49.481 | .0693 | .8174 | 4.9214 | PHE |
| ***TOTALS*** | | | | 2.5176 | 16.6087 | 100 | |

RECOVERED NITROGEN= 83.3647252%

# APPENDIX C

## RAW DATA, ANOVA TABLES (SAS OUTPUT)

## Mean Feed Intake of Chicks on Different Days

| BATT | N | FEED1 | FEED2 | FEED4 | FEED5 | FEED7 | WT1 |
|---|---|---|---|---|---|---|---|
| 4 | 10 | 24.7000000 | 73.0000000 | 106.300000 | 114.100000 | 175.000000 | 81.8690000 |
| 6 | 6 | 37.6000000 | 92.3333333 | 125.333333 | 179.000000 | 267.416667 | 85.3333333 |
| 9 | 8 | 27.3333333 | 78.2222222 | 113.000000 | 129.111111 | 172.000000 | 70.9788889 |

| K | N | FEED1 | FEED2 | FEED4 | FEED5 | FEED7 | WT1 |
|---|---|---|---|---|---|---|---|
| 0 | 2 | 29.5000000 | 47.500000 | 106.000000 | 109.000000 | 236.500000 | 85.0600000 |
| 1 | 5 | 29.0000000 | 75.800000 | 96.200000 | 117.800000 | 162.000000 | 82.8700000 |
| 2 | 6 | 21.8333333 | 65.000000 | 142.166667 | 163.166667 | 220.250000 | 80.6950000 |
| 3 | 5 | 34.0000000 | 115.600000 | 104.800000 | 152.400000 | 232.900000 | 79.0340000 |
| 4 | 4 | 28.7500000 | 86.250000 | 80.750000 | 118.250000 | 132.750000 | 74.8575000 |
| 5 | 3 | 32.6666667 | 110.000000 | 146.333333 | 118.666667 | 200.833333 | 69.1833333 |

| SIDE | BATT | N | FEED1 | FEED2 | FEED4 | FEED5 | FEED7 | WT1 |
|---|---|---|---|---|---|---|---|---|
| 0 | 4 | 5 | 25.0000000 | 85.800000 | 118.800000 | 123.800000 | 170.100000 | 82.0560000 |
| 1 | 4 | 5 | 24.4000000 | 60.200000 | 93.800000 | 104.400000 | 179.900000 | 81.6820000 |
| 0 | 6 | 3 | 46.6666667 | 133.666667 | 133.666667 | 231.000000 | 289.666667 | 88.3333333 |
| 1 | 6 | 3 | 28.3333333 | 51.000000 | 117.000000 | 127.000000 | 245.166667 | 82.3333333 |
| 0 | 9 | 5 | 29.2000000 | 116.600000 | 124.600000 | 131.400000 | 172.600000 | 69.0420000 |
| 1 | 9 | 4 | 25.0000000 | 32.500000 | 98.500000 | 126.250000 | 171.250000 | 73.4000000 |

| TRT | N | FEED1 | FEED2 | FEED4 | FEED5 | FEED7 | WT1 |
|---|---|---|---|---|---|---|---|
| CB | 3 | 44.6666667 | 51.666667 | 95.000000 | 155.000000 | 202.833333 | 77.2333333 |
| CUB | 3 | 25.0000000 | 76.333333 | 148.666667 | 155.666667 | 260.333333 | 80.2900000 |
| DB | 3 | 8.3333333 | 101.666667 | 80.666667 | 64.000000 | 177.500000 | 79.4300000 |
| DUB | 4 | 36.0000000 | 111.000000 | 146.000000 | 123.500000 | 187.250000 | 71.3675000 |
| FB | 3 | 18.3333333 | 56.333333 | 84.666667 | 75.000000 | 91.833333 | 76.9533333 |
| FUB | 3 | 46.6666667 | 74.000000 | 135.000000 | 179.333333 | 193.000000 | 81.9733333 |
| SB | 3 | 48.3333333 | 121.000000 | 88.666667 | 214.000000 | 245.333333 | 81.6900000 |
| SUB | 3 | 0.0000000 | 36.666667 | 106.666667 | 118.000000 | 213.666667 | 81.7733333 |

FEED1=Mean intake of feed by chicks at the end of day 2
FEED2=Mean intake of feed by chicks at the end of day 3
FEED3=Mean intake of feed by chicks at the end of day 4
FEED4=Mean intake of feed by chicks at the end of day 5
FEED5=Mean intake of feed by chicks at the end of day 6
FEED6=Mean intake of feed by chicks at the end of day 7
FEED7=Mean intake of feed by chicks at the end ofdays 8, 9 and 10.

Mean weight of chicks on different days
and different intervals of days

| BATT | N | WT2 | WT4 | WT21 | WT41 | WT42 |
|---|---|---|---|---|---|---|
| 4 | 10 | 125.000000 | 126.833000 | 43.1310000 | 44.9640000 | 1.8330000 |
| 6 | 6 | 140.295000 | 169.265000 | 54.9616667 | 83.9316667 | 28.9700000 |
| 9 | 8 | 117.721250 | 129.037500 | 46.8075000 | 58.1237500 | 11.3162500 |

| K | N | WT2 | WT4 | WT21 | WT41 | WT42 |
|---|---|---|---|---|---|---|
| 0 | 2 | 131.165000 | 136.91.000 | 46.1050000 | 51.8550000 | 5.7500000 |
| 1 | 5 | 120.454000 | 129.894000 | 37.5840000 | 47.0240000 | 9.4400000 |
| 2 | 6 | 129.255000 | 152.831667 | 48.5600000 | 72.1366667 | 23.5766667 |
| 3 | 4 | 136.917500 | 150.292500 | 56.0000000 | 69.3750000 | 13.3750000 |
| 4 | 4 | 120.392500 | 121.590000 | 45.8350000 | 47.0325000 | 1.1975000 |
| 5 | 3 | 121.390000 | 129.466667 | 52.2366667 | 60.3133333 | 8.0766667 |

| SIDE | BATT | N | WT2 | WT4 | WT21 | WT41 | WT42 |
|---|---|---|---|---|---|---|---|
| 0 | 4 | 5 | 130.866000 | 130.346000 | 48.8100000 | 48.2900000 | -0.5200000 |
| 1 | 4 | 5 | 119.134000 | 123.320000 | 37.4520000 | 41.6380000 | 4.1860000 |
| 0 | 6 | 3 | 150.723333 | 177.973333 | 62.3900000 | 89.6400000 | 27.2500000 |
| 1 | 6 | 3 | 129.866667 | 160.556667 | 47.5333333 | 78.2233333 | 30.6900000 |
| 0 | 9 | 4 | 120.792500 | 135.342500 | 52.3650000 | 66.9150000 | 14.5500000 |
| 1 | 9 | 4 | 114.650000 | 122.732500 | 41.2500000 | 49.3325000 | 8.0825000 |

| TRT | N | WT_ | WT4 | WT21 | WT41 | WT42 |
|---|---|---|---|---|---|---|
| CB | 3 | 124.390000 | 147.733333 | 47.1566667 | 70.5000000 | 23.3433333 |
| CUB | 3 | 135.890000 | 144.050000 | 55.6000000 | 63.7600000 | 8.1600000 |
| DB | 2 | 120.750000 | 112.500000 | 37.3550000 | 29.1050000 | -8.2500000 |
| DUB | 4 | 128.832500 | 144.667500 | 57.4650000 | 73.3000000 | 15.8350000 |
| FB | 3 | 115.966667 | 95.720000 | 37.0133333 | 16.7666667 | -20.2466667 |
| FUB | 3 | 129.056667 | 145.890000 | 47.0833333 | 63.9166667 | 16.8333333 |
| SB | 3 | 137.333333 | 156.990000 | 55.6433333 | 75.3000000 | 19.6566667 |
| SUB | 3 | 116.266667 | 147.133333 | 34.4933333 | 65.3600000 | 30.8666667 |

WT1=Mean weight of chicks/pen/treatment on day 1
WT2=Mean weight of chicks/pen/treatment on day 4
WT3=Mean weight of chicks/pen/treatment on day 7
WT4=Mean weight of chicks/pen/treatment on final day.

WT21=Mean weight gain of chicks between day 1 and day 4
WT32=Mean weight gain of chicks between day 2 and day 7
WT42=Mean weight gain of chicks between day 4 and day 10
WT41=Mean weight gain of chicks between day 1 and day 10
WT43=Mean weight gain of chicks between day 7 and day 10
WT31=Mean weight gain of chicks between day 1 and day 7

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: WT43

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PR > F | R-SQUARE | C.V. |
|---|---|---|---|---|---|---|---|
| MODEL | 7 | 3155.44612754 | 450.77801822 | 3.51 | 0.0195 | 0.621245 | 33.1828 |
| ERROR | 15 | 1923.78333333 | 128.25222222 | | ROOT MSE | | WT43 MEAN |
| CORRECTED TOTAL | 22 | 5079.22946087 | | | 11.32484977 | | 34.12869565 |

| SOURCE | DF | ANOVA SS | F VALUE | PR > F |
|---|---|---|---|---|
| TRT | 7 | 3155.44612754 | 3.51 | 0.0195 |

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: WT4

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PR > F | R-SQUARE | C.V. |
|---|---|---|---|---|---|---|---|
| MODEL | 7 | 8753.26617500 | 1250.46659643 | 2.72 | 0.0464 | 0.542945 | 15.5310 |
| ERROR | 16 | 7368.57660833 | 460.53603802 | | ROOT MSE | | WT4 MEAN |
| CORRECTED TOTAL | 23 | 16121.84278333 | | | 21.46010340 | | 138.17583333 |

| SOURCE | DF | ANOVA SS | F VALUE | PR > F |
|---|---|---|---|---|
| TRT | 7 | 8753.26617500 | 2.72 | 0.0464 |

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: WT42

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PR > F | R-SQUARE | C.V. |
|---|---|---|---|---|---|---|---|
| MODEL | 12 | 6979.64517318 | 581.63709776 | 4.07 | 0.0134 | 0.816360 | 101.4330 |
| ERROR | 11 | 1570.07016016 | 142.73365092 | | ROOT MSE | | WT42 MEAN |
| CORRECTED TOTAL | 23 | 8549.71533333 | | | 11.94711894 | | 11.77833333 |

| SOURCE | DF | TYPE I SS | F VALUE | PR > F | DF | TYPE III SS | F VALUE | PR > F |
|---|---|---|---|---|---|---|---|---|
| BATT | 2 | 2764.12513583 | 9.68 | 0.0038 | 2 | 894.93029137 | 3.13 | 0.0837 |
| SIDE(BATT) | 3 | 156.77360250 | 0.37 | 0.7789 | 3 | 347.09856888 | 0.81 | 0.5141 |
| TRT | 7 | 4058.74643484 | 4.06 | 0.0193 | 7 | 4058.74643484 | 4.06 | 0.0193 |

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: FEED7

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PR > F | R-SQUARE | C.V. |
|---|---|---|---|---|---|---|---|
| MODEL | 12 | 78662.58517322 | 6555.21543110 | 3.47 | 0.0203 | 0.776075 | 22.1776 |
| ERROR | 12 | 22696.91482678 | 1891.40956890 | | ROOT MSE | | FEED7 MEAN |
| CORRECTED TOTAL | 24 | 101359.50000000 | | | 43.49033880 | | 196.10000000 |

| SOURCE | DF | TYPE I SS | F VALUE | PR > F | DF | TYPE III SS | F VALUE | PR > F |
|---|---|---|---|---|---|---|---|---|
| BATT | 2 | 40195.79166667 | 10.63 | 0.0022 | 2 | 23136.28530588 | 6.12 | 0.0147 |
| SIDE(BATT) | 3 | 3214.52500000 | 0.57 | 0.6475 | 3 | 1039.35312001 | 0.18 | 0.9058 |
| TRT | 7 | 35252.26850656 | 2.66 | 0.0654 | 7 | 35252.26850656 | 2.66 | 0.0654 |

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: FEEDG

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PR > F | R-SQUARE | C.V. |
|---|---|---|---|---|---|---|---|
| MODEL | 12 | 29832.56842303 | 2486.04736859 | 1.39 | 0.2950 | 0.603184 | 31.0015 |
| ERROR | 11 | 19625.93157697 | 1784.17559791 | | ROOT MSE | | FEEDG MEAN |
| CORRECTED TOTAL | 23 | 49458.50000000 | | | 42.23950281 | | 136.25000000 |

| SOURCE | DF | TYPE I SS | F VALUE | PR > F | DF | TYPE III SS | F VALUE | PR > F |
|---|---|---|---|---|---|---|---|---|
| BATT | 2 | 8292.31111111 | 2.32 | 0.1439 | 2 | 9339.43130559 | 2.62 | 0.1176 |
| SIDE(BATT) | 3 | 7925.02222222 | 1.48 | 0.2736 | 3 | 5424.68528472 | 1.01 | 0.4236 |
| TRT | 7 | 13615.23508970 | 1.09 | 0.4307 | 7 | 13615.23508970 | 1.09 | 0.4307 |

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: WT41

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PR > F | R-SQUARE | C.V. |
|---|---|---|---|---|---|---|---|
| MODEL | 12 | 12574.71020689 | 1047.89251724 | 6.24 | 0.0024 | 0.871862 | 21.9349 |
| ERROR | 11 | 1848.11704311 | 168.01064028 | | ROOT MSE | | WT41 MEAN |
| CORRECTED TOTAL | 23 | 14422.82725000 | | | 12.96189185 | | 59.09250000 |

| SOURCE | DF | TYPE I SS | F VALUE | PR > F | DF | TYPE III SS | F VALUE | PR > F |
|---|---|---|---|---|---|---|---|---|
| BATT | 2 | 5705.55813917 | 16.98 | 0.0004 | 2 | 2121.44351776 | 6.31 | 0.0149 |
| SIDE(BATT) | 3 | 924.42178917 | 1.83 | 0.1993 | 3 | 1081.41248369 | 2.15 | 0.1524 |
| TRT | 7 | 5944.73027856 | 5.05 | 0.0088 | 7 | 5944.73027856 | 5.05 | 0.0088 |

MEANS

| BATT | N | WT3 | WT31 |
|---|---|---|---|
| 4 | 10 | 98.153000 | 16.2840000 |
| 6 | 5 | 119.910000 | 36.0100000 |
| 9 | 9 | 91.923333 | 20.9444444 |

| K | N | WT3 | WT31 |
|---|---|---|---|
| 0 | 2 | 106.200000 | 21.1400000 |
| 1 | 5 | 100.946000 | 18.0760000 |
| 2 | 6 | 111.046667 | 30.3516667 |
| 3 | 4 | 95.317500 | 19.6500000 |
| 4 | 4 | 91.542500 | 16.9850000 |
| 5 | 3 | 92.513333 | 23.3600000 |

| SIDE | BATT | N | WT3 | WT31 |
|---|---|---|---|---|
| 0 | 4 | 5 | 99.600000 | 17.5440000 |
| 1 | 4 | 5 | 96.706000 | 15.0240000 |
| 0 | 6 | 2 | 123.125000 | 36.8750000 |
| 1 | 6 | 3 | 117.766667 | 35.4333333 |
| 0 | 9 | 5 | 89.488000 | 20.4460000 |
| 1 | 9 | 4 | 94.967500 | 21.5675000 |

| TRT | N | WT3 | WT31 |
|---|---|---|---|
| CB | 3 | 102.466667 | 25.2333333 |
| CUB | 3 | 107.583333 | 27.2933333 |
| DB | 3 | 85.043333 | 5.6133333 |
| DUB | 4 | 106.292500 | 34.9250000 |
| FB | 3 | 86.156667 | 7.2033333 |
| FUB | 3 | 109.266667 | 27.2933333 |
| SB | 2 | 101.935000 | 25.6500000 |
| SUB | 3 | 102.600000 | 20.8266667 |

GENERAL LINEAR MODELS PROCEDURE

MEANS

| BATT | N | FEED3 |
|---|---|---|
| 4 | 10 | 119.300000 |
| 6 | 5 | 115.600000 |
| 9 | 7 | 95.571429 |

| K | N | FEED3 |
|---|---|---|
| 0 | 2 | 112.500000 |
| 1 | 5 | 109.200000 |
| 2 | 6 | 112.500000 |
| 3 | 4 | 118.750000 |
| 4 | 4 | 93.500000 |
| 5 | 1 | 145.000000 |

| SIDE | BATT | N | FEED3 |
|---|---|---|---|
| 0 | 4 | 5 | 157.200000 |
| 1 | 4 | 5 | 81.400000 |
| 0 | 6 | 2 | 119.000000 |
| 1 | 6 | 3 | 113.333333 |
| 0 | 9 | 3 | 112.666667 |
| 1 | 9 | 4 | 82.750000 |

| TRT | N | FEED3 |
|---|---|---|
| CB | 3 | 108.333333 |
| CUB | 3 | 118.000000 |
| DB | 3 | 83.000000 |
| DUB | 2 | 132.500000 |
| FB | 3 | 123.333333 |
| FUB | 3 | 111.000000 |
| SB | 2 | 133.000000 |
| SUB | 3 | 92.666667 |

VITA

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